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SOFT STARTER AND MONITORING SYSTEM FOR THREE PHASE INDUCTION MOTOR USING PIC

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

in

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Under the guidance of

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ANNA UNIVERSITY : CHENNAI-600 025

BONAFIDE CERTIFICATE

Certified that this project report titled " **SOFT STARTER AND MONITORING SYSTEM FOR THREE PHASE INDUCTION MOTOR USING PIC** " is the bonafide work of

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who carried out the project work under my supervision.

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ABSTRACT

The advent of AC power has led to all round usage of AC machines. The most important AC machine is the three phase induction motor, which is extensively used in many industrial and commercial applications. This project deals with the starting and monitoring system for three phase induction motor.

At present three phase induction motors are started using star-delta starters, which requires manual operation. They also have some disadvantages like bulk in size and more power consumption. In this project, an effective starting system using thyristorised circuit fed from three phase supply is designed for the machine to start smoothly.

Monitoring the electrical parameters of a motor is essential in college laboratories and industries. For measurement, individual meters are used which increase the cost and space. Here an effective monitoring system through computer display is designed to monitor current, voltage, speed and power factor during the running condition.

A PIC microcontroller is used as processor for both starting and monitoring system. Since we have used embedded technology, the hardware is very compact in size and the cost involved is also very less.

ACKNOWLEDGEMENT

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SYMBOLS, ABBREVIATIONS OF NOMENCLATURE

I_{2r}	Rotor current in running condition.
E_2	Rotor induced e.m.f in running condition per phase.
S	Slip of the Three phase induction motor.
R_2	Rotor resistance per phase.
X_2	Rotor reactance per phase.
V_i	Voltage applied across input terminals.
V_o	Regulated output D.C voltage.
GND	Grounded.
PIC	Peripoheral Interface Controller.
ROM	Read Only Memory.
RAM	Random Access Memory.
ADC	Analog to Digital Converter.
DAC	Digital to Analog Converter.
ALU	Arithmetic and Logic Unit.
DOL	Direct On-Line.

DEDICATED TO OUR BELOVED PARENTS AND FRIENDS

CHAPTER 1

1. THREE PHASE INDUCTION MOTOR

1.1 INTRODUCTION:

The induction machine is an important class of electric machines which finds wide applicability as a motor in industry and in its single phase form in several domestic applications. More than 85% of industrial motors in use today are in fact three phase induction motors. It is substantially a constant speed motor with a shunt characteristics; a few percent speed drop from no load to full load. It is a singly-fed motor(stator fed) unlike the synchronous motor which requires A.C supply on the stator side and D.C excitation on the rotor. The torque developed in this motor has its origin in current induction in the rotor which is only possible at non-synchronous speed; hence the name asynchronous machine.

Torque in a synchronous machine on the other hand, is developed only at synchronous speed when the "locking" of the two fields takes place. Therefore, the induction motor is not plagued by the stability problem inherent in the synchronous motor. Since it is a singly-fed machine, it draws its excitation current from the mains to set up the rotating field in the air gap which is essential for its operation. As a consequence it inherently has a power factor less than unity which usually must be corrected by means of shunt capacitors at motor terminals. There is no simple and inexpensive method of controlling the induction motor speed as it is possible in a D.C shunt motor. A wide range of speed control is possible only by expensive circuitry using SCRs. It still finds stiff competition from the D.C shunt motor in such applications.

ADVANTAGES:

* Its cost is low and it is very reliable
* It has a reasonably good power factor
* It requires minimum maintenance.

* It has sufficiently high efficiency. In normal running condition, no brushes are needed. Hence friction losses are reduced

1.2 **CONSTRUCTION:**

An induction motor consists essentially of two main parts.

* a stator
* a rotor

STATOR:

The stator of a induction motor is made up of a number of stampings which are slotted to receive the windings. The stator carries a three phase winding and is fed from a three phase supply. It is wound for a definite number of poles, the exact number of poles being determined by the requirements of speed. Greater the number of poles, lesser the speed and vice versa. Stator winding when supplied with three phase current produce a magnetic flux which is of constant magnitude but revolves at synchronous speed. This revolving magnetic flux induces an e.m.f in the rotor by mutual induction.

ROTOR:

Rotors are of two types. They are,

1. Squirrel - Cage rotor.
2. Phase wound or wound rotor.

SQUIRREL - CAGE ROTOR

Almost 90% of induction motors are squirrel - cage type, because this type of rotor has the simplest and most rugged construction, imaginable and is almost indestructible. The rotor consists of cylindrical laminated core with parallel slots for carrying the rotor conductors which are not wires but consists of heavy bars of copper, aluminium or alloys.

One bar is placed in each slot. The rotor bars are brazed or electrically welded or bolted to two heavy and stout short circuiting end - rings, thus giving a squirrel cage construction.

The rotor slots are usually not quite parallel to the shaft but are purposely given a slight skew. This is useful in two ways.

* It helps to make the motor run quietly by reducing the magnetic hum.
* It helps in reducing the locking tendency of the rotor i.e., the tendency of the rotor teeth to remain under the stator teeth due to the direct magnetic acceleration between the two.

HOW THE ROTOR ROTATE ?

When supply is given to the stator winding, a magnetic flux of constant magnitude but rotating at synchronous speed is set up. The flux passes through the air gap, sweeps past the rotor surface and so cuts the rotor conductors which as yet are stationary. Due to the relative speed between the rotating flux and the stationary conductors an e.m.f is induced in the latter, according to the relative velocity between the flux and the conductors and its direction is given by Fleming's Right Hand rule.

Since the rotor bars form a closed circuit, rotor current is produced whose direction as given by Lenz's law, is such as to oppose the very cause producing it. In this case, the cause which produces the rotor current is a relative velocity between the rotating flux of the stator and the stationary rotor conductors. Hence, to reduce the relative speed, the rotor starts running in the same direction as that of the flux and tries to catch up with the rotating flux.

In practice, the rotor never succeeds in catching up the stator field. If it really did so, there would be no relative speed between the two, hence no rotor e.m.f, no rotor current and so no torque to maintain rotation. that is why the rotor runs at a speed which is always less than that of the stator field.

1.3 NECESSITY OF STARTERS :

In a three phase induction motor, the magnitude of an induced e.m.f depends upon the slip of the induction motor. This induced e.m.f effectively decides the magnitude of the rotor current. The rotor current in the running condition is given by

$$I_{2r} = \frac{s\,E_2}{\sqrt{R_2^2 + (s\,X_2)^2}}$$

But at the start, the speed of the motor is zero and slip is at its maximum i.e. unity. So magnitude of rotor induced e.m.f is very large at start. As rotor conductors are short circuited ,the large induced e.m.f circulates very high current through the rotor at start.

The condition is exactly similar to a transformer with short circuited secondary. Such a transformer when excited by a rated voltage, circulates very high current through short circuited secondary. As secondary current is large, the primary also draws very high current from the supply. When rotor current is high, consequently the stator draws a very high current from the supply. This current can be of the order of 5 to 8 times the full load current, at start. Due to heavy inrush of current at start there is possibility of damage of the motor winding.

Similarly such sudden inrush of current causes large line voltage drop. Thus other appliances connected to the same line may be subjected to voltage spikes which may affect their working. To avoid such effects, it is necessary to limit the current drawn by the motor at start. The **Starter** is a device which is basically used to limit high starting current by supplying reduced voltage to the motor at the time of starting. Such a reduced voltage is applied only for short period and once rotor gets accelerated, full normal rated voltage is applied.

Not only the starter limits the starting current but also provides the protection to the motor against over loading and low voltage situations. The protection against single phasing is also provided by the starter

1.4 TYPES OF STARTERS :

From the expression of rotor current it can be seen that the current at start can be controlled by reducing E_2 which is possible by supplying reduced voltage at start or by increasing the rotor resistance R_2 at start. The second method is possible only in case of slip ring induction motors. The various types of starters based on above two methods of reducing the starting current are as follows

1.4.1 STATOR RESISTANCE STARTER :

In this type, three resistances are added in series with each phase of the stator winding. Initially the resistances are kept maximum in the circuit. Due to this large voltage gets dropped occurs across the high resistances. Hence a reduced voltage gets applied to the stator which reduces the high starting current. The disadvantages are

- Large power losses due to resistances
- Starting torque of the motor reduces due to reduced voltage applied to the stator.

1.4.2 AUTO TRANSFORMER STARTER :

A Three phase star connected auto transformer is used to reduce the voltage applied to the stator. It consists of a suitable change over switch. When the switch is in the start position, the stator is supplied with reduced voltage. This can be normally controlled by tappings provided with auto transformer. It is expensive due to auto transformer and also bulk in size.

1.4.3 STAR – DELTA STARTER :

It uses triple pole double throw (TPST) switch. The switch connects the stator winding in star at start. Hence per phase voltage gets reduced by the factor $1 / \sqrt{3}$. Due to this reduced voltage staring current is limited.

When the switch is thrown on other side, the winding gets connected in delta, across the supply. So it gets normal rated voltage. The windings are connected in delta when motor gathers sufficient speed. The limitation is, it is suitable for normal delta connected motors and the factor by which voltage change is $1 / \sqrt{3}$ which cannot be changed.

1.4.4 ROTOR RESISTANCE STARTER :

In this type, an additional resistance in rotor is included in the form of three phase star connected rheostat. The external resistance is inserted in each phase of the rotor winding through slip ring and brush assembly. Initially maximum resistance is in the circuit. As the motor gathers speed, the resistance is gradually cut off. Limitation of this starter is that it can be used only for slip ring induction motor as in squirrel cage motors, the rotor is permanently short circuited.

1.4.5 DIRECT ON LINE STARTER (DOL) :

Generally these kind of starters are used for low rating motors. Though this starter doesn't reduce the applied voltage, it is used because it protects the motor from various abnormal conditions like over loading, low voltage, etc. The starting current will not cause damage to the motor unless the motor is repeatedly started and stopped in a short space of time. This is called 'fast cycling'.

When very large motors are started direct-on-line they cause a disturbance of voltage (voltage dip) on the supply lines due to the large starting current surge. This voltage disturbance may result in the malfunction of other electrical equipment connected to the supply.

Thus all the three phase induction motors require some kind of starter during their starting and running conditions.

1.5 OBJECTIVE :

The main objective of our project is to provide a complete testing kit for the Three phase Induction motors. We have chosen three phase induction motor mainly because of its application in large industries and college laboratories.
In our project we combine two most important operations namely

- SOFT STARTING OF THE MOTOR
- MONITORING SYSTEM (CURRENT, VOLTAGE, POWER FACTOR & SPEED) FOR THE MOTOR DURING THE RUN TIME.

In any case, starting of the motor plays an important role as seen in previous section. Here an effective way of staring is employed through which the motor runs smoothly. Also monitoring of the parameters is essential during the running condition. Here the parameters are monitored through personal computer during the running condition.

The complete block diagram of this project is shown in fig 1.1. During the soft starting operation contactor 1 gets closed while contactor 2 remains opened. After the motor has attained its rated speed, the monitoring system begins to function. During this operation contactor 1 gets opened while contactor gets closed. The relay circuit controls the switching operation of the contactors. The relay circuit operates according to the signals received from the PIC. The output from PIC is interfaced with computer through which the parameters are displayed.

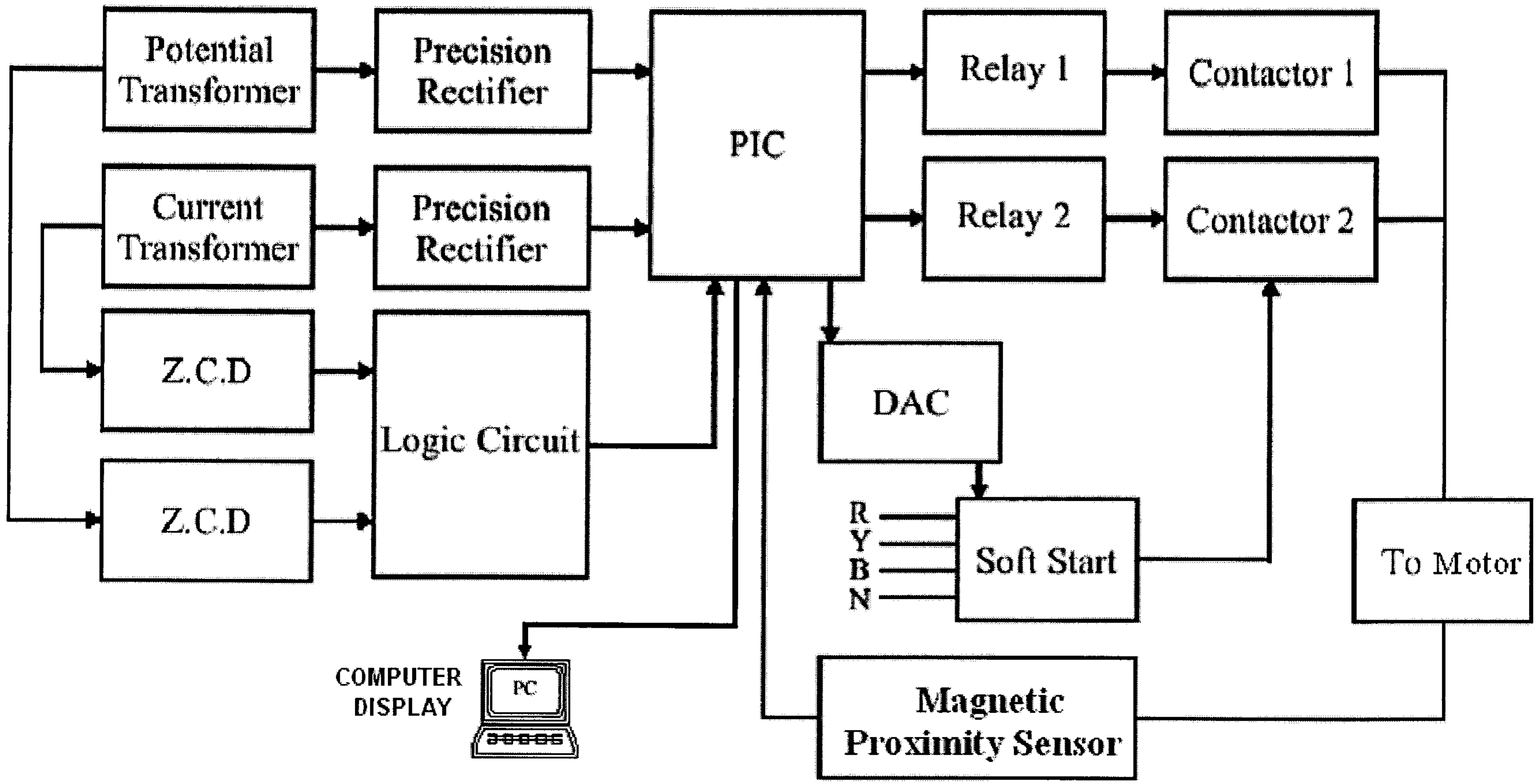


FIG 1.1 COMPLETE BLOCK DIAGRAM

CHAPTER 2

2. MICRO CONTROLLER

2.1 CONCEPTS OF MICROCONTROLLER :

Microcontroller is a general purpose device, which integrates a number of the components of a microprocessor system on to single chip. It has inbuilt CPU, memory and peripherals to make it as a mini computer. A microcontroller combines on to the same microchip:

- The CPU core
- Memory(both ROM and RAM)
- Some parallel digital i/o

Microcontrollers will combine other devices such as:

- A timer module to allow the microcontroller to perform tasks for certain time periods.
- A serial i/o port to allow data to flow between the controller and other devices such as a PIC or another microcontroller.
- An ADC to allow the microcontroller to accept analogue input data for processing.

Microcontrollers are :

- Smaller in size
- Consumes less power
- Inexpensive

Micro controller is a stand alone unit ,which can perform functions on its own without any requirement for additional hardware like i/o ports and external memory.

The heart of the microcontroller is the CPU core. In the past, this has traditionally been based on a 8-bit microprocessor unit. For example Motorola uses a basic 6800 microprocessor core in their 6805/6808 microcontroller devices.

In the recent years, microcontrollers have been developed around specifically designed CPU cores, for example the microchip PIC range of microcontrollers.

2.2 INTRODUCTION TO PIC :

The microcontroller that has been used for this project is from PIC series. PIC microcontroller is the first RISC based microcontroller fabricated in CMOS (complimentary metal oxide semiconductor) that uses separate bus for instruction and data allowing simultaneous access of program and data memory.

The main advantage of CMOS and RISC combination is low power consumption resulting in a very small chip size with a small pin count. The main advantage of CMOS is that it has immunity to noise than other fabrication techniques.

PIC (16F877) :

Various microcontrollers offer different kinds of memories. EEPROM, EPROM, FLASH etc. are some of the memories of which FLASH is the most recently developed. Technology that is used in pic16F877 is flash technology, so that data is retained even when the power is switched off. Easy Programming and Erasing are other features of PIC 16F877.

PIC START PLUS PROGRAMMER :

The PIC start plus development system from microchip technology provides the product development engineer with a highly flexible low cost microcontroller design tool set for all microchip PIC micro devices. The picstart plus development system includes PIC start plus development programmer and mplab ide.

The PIC start plus programmer gives the product developer ability to program user software in to any of the supported microcontrollers. The PIC start plus software running under mplab provides for full interactive control over the programmer.

2.3 SPECIAL FEATURES OF PIC MICROCONTROLLER :

CORE FEATURES :

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input

  DC - 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory,

  Up to 368 x 8 bytes of Data Memory (RAM)

  Up to 256 x 8 bytes of EEPROM data memory
- Pin out compatible to the PIC16C73/74/76/77
- Interrupt capability (up to 14 internal/external
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC Oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS EPROM/EEPROM technology
- Fully static design
- In-Circuit Serial Programming (ICSP) via two pins
- Only single 5V source needed for programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.5V to 5.5V
- High Sink/Source Current: 25 mA

- Commercial and Industrial temperature ranges
- Low-power consumption:

  < 2mA typical @ 5V, 4 MHz

  20mA typical @ 3V, 32 kHz

  < 1mA typical standby current

PERIPHERAL FEATURES :

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules

  Capture is 16-bit, max resolution is 12.5 ns,

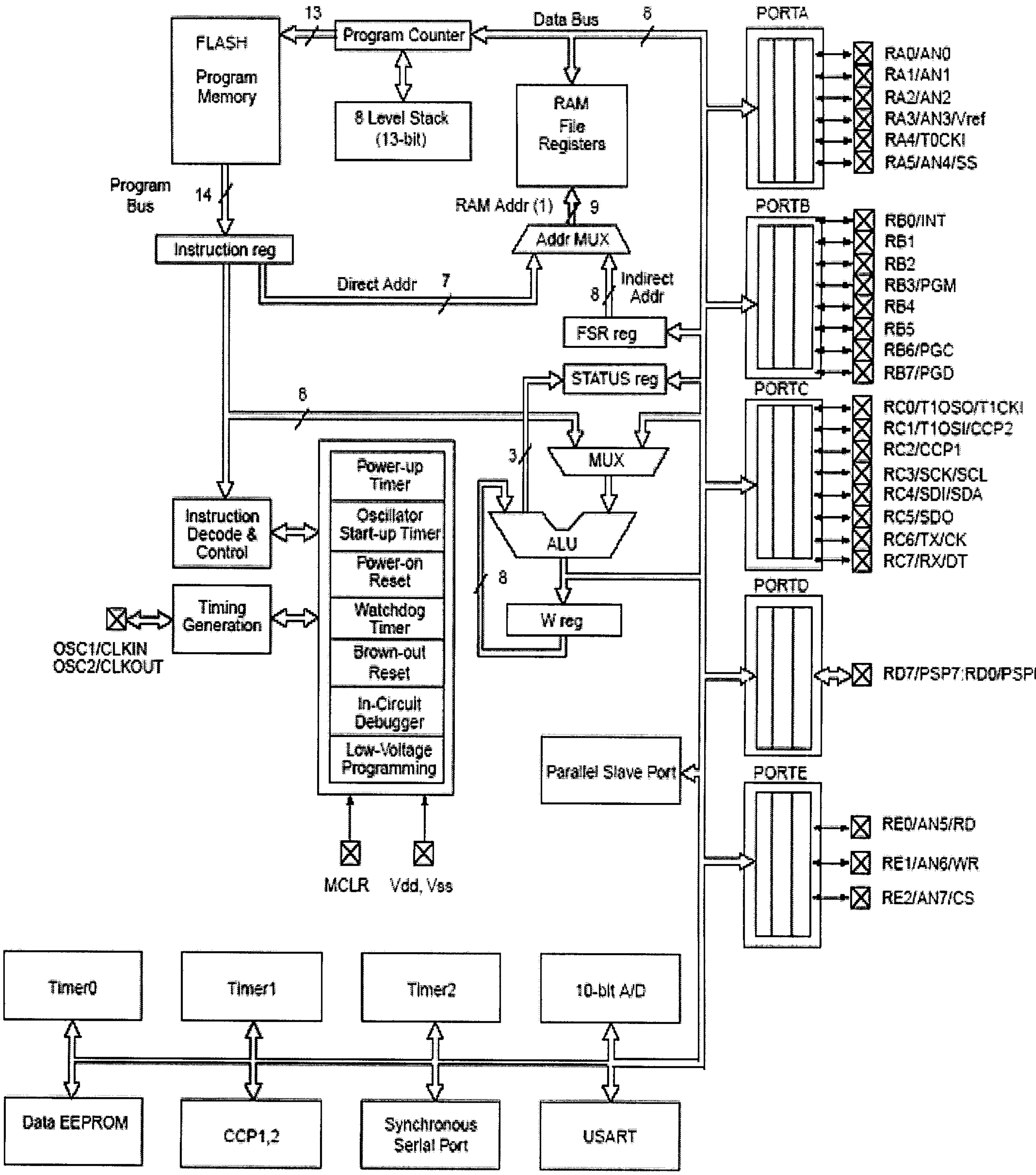
  Compare is 16-bit, max resolution is 200 ns,

  PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI. (Master Mode) and I2C. (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9- bit address detection.
- Brown-out detection circuitry **for Brown-out Reset (BOR)**

2.4 ARCHITECTURE OF PIC 16F877 :

The complete architecture of PIC 16F877 is shown in the fig 2.1. Table 2.1 gives details about the specifications of PIC 16F877. Fig 2.2 shows the complete pin diagram of the IC PIC 16F877.

FIG 2.1 ARCHITECTURE OF PIC 16F877



Note 1: Higher order bits are from the STATUS register.

TABLE 2.1 SPECIFICATIONS

DEVICE	PROGRAM FLASH	DATA MEMORY	DATA EEPROM
PIC 16F877	8K	368 Bytes	256 Bytes

FIG 2.2 PIN DIAGRAM OF PIC 16F877

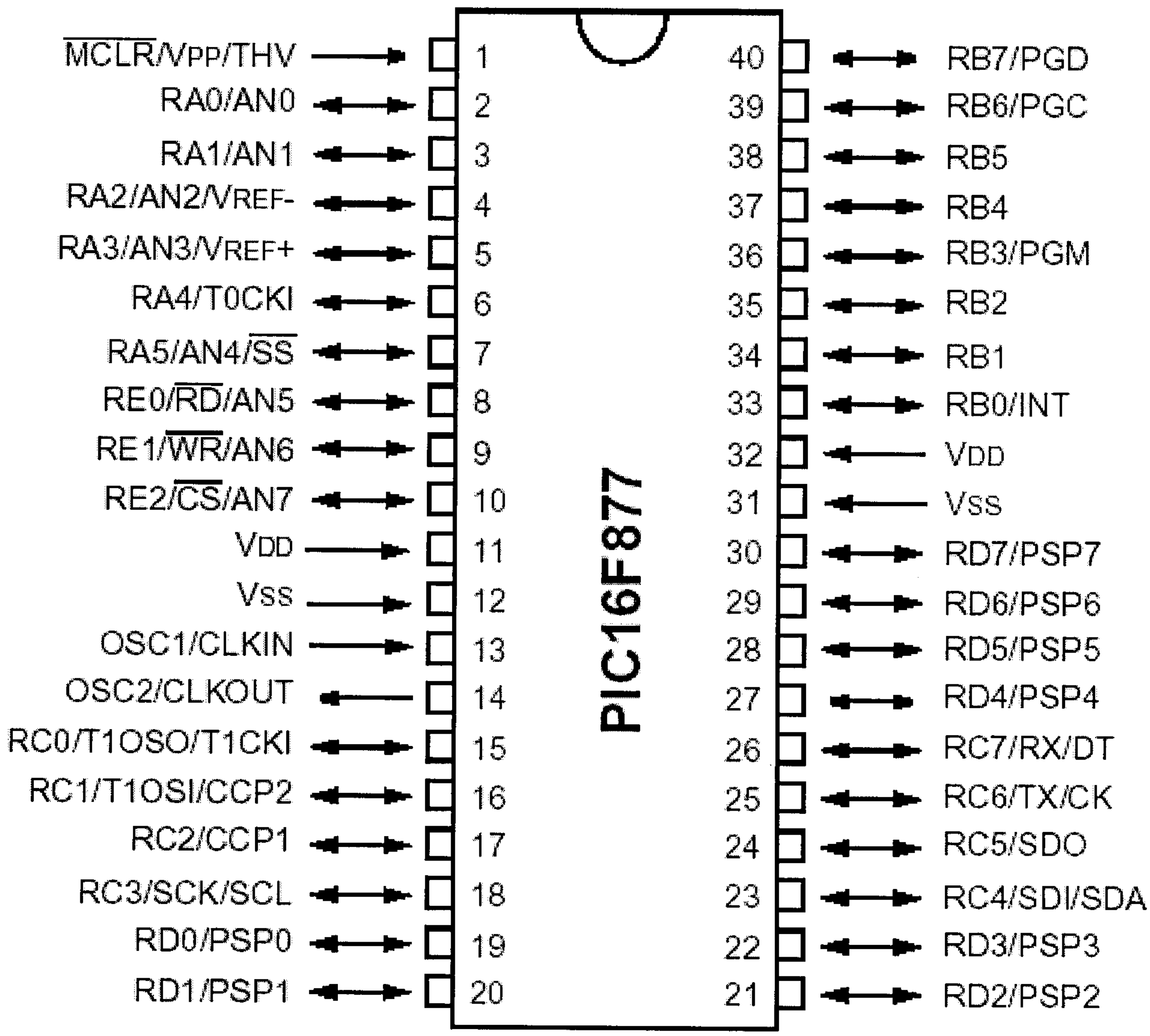


TABLE 2.2 PIN OUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/V_{PP}/THV	1	2	18	I/P	ST	Master clear (reset) input or programming voltage input or high voltage test mode control. This pin is an active low reset to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1
RA2/AN2/V_{REF-}	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage
RA3/AN3/V_{REF+}	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input
RB4	37	41	14	I/O	TTL	Interrupt on change pin.
RB5	38	42	15	I/O	TTL	Interrupt on change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming data.

Legend: I = input O = output I/O = input/output P = power

— = Not used TTL = TTL input ST = Schmitt Trigger input

Note

1. This buffer is a Schmitt Trigger input when configured as an external interrupt
2. This buffer is a Schmitt Trigger input when used in serial programming mode.
3. This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4. This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/ PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/ output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
V_{SS}	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
V_{DD}	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power

— = Not used TTL = TTL input ST = Schmitt Trigger input

Note :

1. This buffer is a Schmitt Trigger input when configured as an external interrupt.
2. This buffer is a Schmitt Trigger input when used in serial programming mode.
3. This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4. This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

2.5 I/O PORTS :

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

Additional Information on I/O ports may be found in the IC micro™ Mid-Range Reference Manual,

PORTA AND THE TRISA REGISTER :

PORTA is a 6-bit wide bi-directional port. The corresponding data direction register is TRISA. Setting a TRISA bit (=1) will make the corresponding PORTA pin an input, i.e., put the corresponding output driver in a Hi-impedance mode. Clearing a TRISA bit (=0) will make the corresponding PORTA pin an output, i.e., put the contents of the output latch on the selected pin. Reading the PORTA register reads the status of the pins whereas writing to it will write to the port latch. All write operations are read-modify-write operations. Therefore a write to a port implies that the port pins are read; this value is modified, and then written to the port data latch. Pin RA4 is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. The RA4/T0CKI pin is a Schmitt Trigger input and an open drain output. All other RA port pins have TTL input levels and full CMOS output drivers. Other PORTA pins are multiplexed with analog inputs and analog VREF input. The operation of each pin is selected by clearing/setting the control bits in the ADCON1 register (A/D Control Register1).

The TRISA register controls the direction of the RA pins, even when they are being used as analog inputs. The user must ensure the bits in the TRISA register are maintained set when using them as analog inputs.

TABLE 2.3 PORT A FUNCTION

Name	Bit#	Buffer	Function
RA0/AN0	bit0	TTL	Input/output or analog input
RA1/AN1	bit1	TTL	Input/output or analog input
RA2/AN2	bit2	TTL	Input/output or analog input
RA3/AN3/VREF	bit3	TTL	Input/output or analog input or VREF
RA4/T0CKI	bit4	ST	Input/output or external clock input for Timer0 Output is open drain type
RA5/$\overline{SS}$/AN4	bit5	TTL	Input/output or slave select input for synchronous serial port or analog input

Legend: TTL = TTL input, ST = Schmitt Trigger input

TABLE 2.4 SUMMARY OF REGISTERS ASSOCIATED WITH PORTA

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
05h	PORTA	—	—	RA5	RA4	RA3	RA2	RA1	RA0	--0x 0000	--0u 0000
85h	TRISA	—	—	PORTA Data Direction Register						--11 1111	--11 1111
9Fh	ADCON1	—	—	ADFM	—	PCFG3	PCFG2	PCFG1	PCFG0	--0- 0000	--0- 0000

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTA.

PORTB AND TRISB REGISTER :

PORTB is an 8-bit wide bi-directional port. The corresponding data direction register is TRISB. Setting a TRISB bit (=1) will make the corresponding PORTB pin an input, i.e., put the corresponding output driver in a hi-impedance mode. Clearing a TRISB bit (=0) will make the corresponding PORTB pin an output, i.e., put the contents of the output latch on the selected pin. Three pins of PORTB are multiplexed with the Low Voltage Programming function; RB3/PGM, RB6/PGC and RB7/PGD. The alternate functions of these pins are described in the Special Features Section. Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-ups.

This is performed by clearing bit RBPU (OPTION_REG<7>). The weak pull-up is automatically turned off when the port pin is configured as an output. The pull-ups are disabled on a Power-on Reset.

Four of PORT B's pins, RB7:RB4, have an interrupt on change feature. Only pins configured as inputs can cause this interrupt to occur (i.e. any RB7:RB4 pin configured as an output is excluded from the interrupt on change comparison). The input pins (of RB7:RB4) are compared with the old value latched on the last read of PORTB. The "mismatch" outputs of RB7:RB4 are OR'ed together to generate the RB Port Change Interrupt with flag bit RBIF (INTCON<0>). This interrupt can wake the device from SLEEP. The user, in the interrupt service routine, can clear the interrupt in the following manner:

a) Any read or write of PORTB. This will end the mismatch condition.

b) Clear flag bit RBIF. A mismatch condition will continue to set flag bit RBIF. Reading PORTB will end the mismatch condition, and allow flag bit RBIF to be cleared. The interrupt on change feature is recommended for wake-up on key depression operation and operations where PORTB is only used for the interrupt on change feature. Polling of PORTB is not recommended while using the interrupt on change feature. This interrupt on mismatch feature, together with software configurable pull-ups on these four pins, allow easy interface to a keypad and make it possible for wake-up on key depression

TABLE 2.5 PORT B FUNCTIONS

Name	Bit#	Buffer	Function
RB0/INT	bit0	TTL/ST(1)	Input/output pin or external interrupt input. Internal software programmable weak pull-up.
RB1	bit1	TTL	Input/output pin. Internal software programmable weak pull-up.
RB2	bit2	TTL	Input/output pin. Internal software programmable weak pull-up.
RB3/PGM	bit3	TTL	Input/output pin or programming pin in LVP mode. Internal software programmable weak pull-up.
RB4	bit4	TTL	Input/output pin (with interrupt on change). Internal software programmable weak pull-up.
RB5	bit5	TTL	Input/output pin (with interrupt on change). Internal software programmable weak pull-up.
RB6/PGC	bit6	TTL/ST(2)	Input/output pin (with interrupt on change) or In-Circuit Debugger pin. Internal software programmable weak pull-up. Serial programming clock.
RB7/PGD	bit7	TTL/ST(2)	Input/output pin (with interrupt on change) or In-Circuit Debugger pin. Internal software programmable weak pull-up. Serial programming data.

Legend: TTL = TTL input, ST = Schmitt Trigger input
Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in serial programming mode.

TABLE 2.6 SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

Addre	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
06h, 1	PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	xxxx xxxx	uuuu uuuu
86h, 1	TRISB	PORTB Data Direction Register								1111 1111	1111 1111
81h, 1	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111

Legenc : unknown, u = unchanged. Shaded cells are not used by PORTB.

PORTC AN HE TRISC REGISTER :

PORTC is an 8-bit wide bi-directional port. The correspondir data direction register is TRISC. Setting a TRISC bit (=1) will make the correspondir PORTC pin an input, i.e., put the corresponding output driver in a hi-impedance n le. Clearing a TRISC bit (=0) will make the corresponding PORTC pin an output, i.e., the contents of the output latch on the selected pin. PORTC is multiplexed with several ripheral functions. PORTC pins have Schmitt Trigger input buffers.

When the I2C module is enabled, the PORTC (3:4) pins can be configured with normal I2C levels or with SMBUS levels by using the CKE bit (SSPSTAT <6>). When enabling peripheral functions, care should be taken in defining TRIS bits for each PORTC pin. Some peripherals override the TRIS bit to make a pin an output, while other peripherals override the TRIS bit to make a pin an input. Since the TRIS bit override is in effect while the peripheral is enabled, read-modify write instructions (BSF, BCF, XORWF) with TRISC as destination should be avoided. The user should refer to the corresponding peripheral section for the correct TRIS bit settings.

TABLE 2.7 PORTC FUNCTIONS

Name	Bit#	Buffer Type	Function
RC0/T1OSO/T1CKI	bit0	ST	Input/output port pin or Timer1 oscillator output/Timer1 clock input
RC1/T1OSI/CCP2	bit1	ST	Input/output port pin or Timer1 oscillator input or Capture2 input/ Compare2 output/PWM2 output
RC2/CCP1	bit2	ST	Input/output port pin or Capture1 input/Compare1 output/PWM1 output
RC3/SCK/SCL	bit3	ST	RC3 can also be the synchronous serial clock for both SPI and I^2C modes.
RC4/SDI/SDA	bit4	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	bit5	ST	Input/output port pin or Synchronous Serial Port data output
RC6/TX/CK	bit6	ST	Input/output port pin or USART Asynchronous Transmit or Synchronous Clock
RC7/RX/DT	bit7	ST	Input/output port pin or USART Asynchronous Receive or Synchronous Data

Legend: ST = Schmitt Trigger input

TABLE 2.8 SUMMARY OF REGISTERS ASSOCIATED WITH PORTC

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
07h	PORTC	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	xxxx xxxx	uuuu uuuu
87h	TRISC	PORTC Data Direction Register								1111 1111	1111 1111

Legend: x = unknown, u = unchanged.

PORTD AND TRISD REGISTERS :

This section is not applicable to the 28-pin devices. PORTD is an 8-bit port with Schmitt Trigger input buffers. Each pin is individually configurable as an input or output. PORTD can be configured as an 8-bit wide microprocessor Port (parallel slave port) by setting control bit PSPMODE (TRISE<4>). In this mode, the input buffers are TTL.

TABLE 2.9 PORTD FUNCTIONS

Name	Bit#	Buffer Type	Function
RD0/PSP0	bit0	ST/TTL(1)	Input/output port pin or parallel slave port bit0
RD1/PSP1	bit1	ST/TTL(1)	Input/output port pin or parallel slave port bit1
RD2/PSP2	bit2	ST/TTL(1)	Input/output port pin or parallel slave port bit2
RD3/PSP3	bit3	ST/TTL(1)	Input/output port pin or parallel slave port bit3
RD4/PSP4	bit4	ST/TTL(1)	Input/output port pin or parallel slave port bit4
RD5/PSP5	bit5	ST/TTL(1)	Input/output port pin or parallel slave port bit5
RD6/PSP6	bit6	ST/TTL(1)	Input/output port pin or parallel slave port bit6
RD7/PSP7	bit7	ST/TTL(1)	Input/output port pin or parallel slave port bit7

Legend: ST = Schmitt Trigger input TTL = TTL input
Note 1: Input buffers are Schmitt Triggers when in I/O mode and TTL buffer when in Parallel Slave Port Mode.

TABLE 2.10 SUMMARY OF REGISTERS ASSOCIATED WITH PORTD

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
08h	PORTD	RD7	RD6	RD5	RD4	RD3	RD2	RD1	RD0	xxxx xxxx	uuuu uuuu
88h	TRISD	PORTD Data Direction Register								1111 1111	1111 1111
89h	TRISE	IBF	OBF	IBOV	PSPMODE	—	PORTE Data Direction Bits			0000 -111	0000 -111

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by PORTD.

PORTE AND TRISE REGISTER :

PORTE has three pins RE0/RD/AN5, RE1/WR/AN6 and RE2/CS/AN7, which are individually configurable as inputs or outputs. These pins have Schmitt Trigger input buffers.

The PORTE pins become control inputs for the microprocessor port when bit PSPMODE (TRISE<4>) is set. In this mode, the user must make sure that the TRISE<2:0> bits are set (pins are configured as digital inputs). Ensure ADCON1 is configured for digital I/O. In this mode the input buffers are TTL.

PORTE pins are multiplexed with analog inputs. When selected as an analog input, these pins will read as '0's. TRISE controls the direction of the RE pins, even when they are being used as analog inputs. The user must make sure to keep the pins configured as inputs when using them as analog inputs.

TABLE 2.11 PORTE FUNCTIONS

Name	Bit#	Buffer Type	Function
RE0/$\overline{RD}$/AN5	bit0	ST/TTL[1]	Input/output port pin or read control input in parallel slave port mode or analog input: $\overline{RD}$ 1 = Not a read operation 0 = Read operation. Reads PORTD register (if chip selected)
RE1/$\overline{WR}$/AN6	bit1	ST/TTL[1]	Input/output port pin or write control input in parallel slave port mode or analog input: $\overline{WR}$ 1 =Not a write operation 0 =Write operation. Writes PORTD register (if chip selected)
RE2/$\overline{CS}$/AN7	bit2	ST/TTL[1]	Input/output port pin or chip select control input in parallel slave port mode or analog input: $\overline{CS}$ 1 = Device is not selected 0 = Device is selected

Legend: ST = Schmitt Trigger input TTL = TTL input

Note 1: Input buffers are Schmitt Triggers when in I/O mode and TTL buffers when in Parallel Slave Port Mode.

TABLE 2.12 SUMMARY OF REGISTERS ASSOCIATED WITH PORTE

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
09h	PORTE	—	—	—	—	—	RE2	RE1	RE0	---- -xxx	---- -uuu
89h	TRISE	IBF	OBF	IBOV	PSPMODE	—	PORTE Data Direction Bits			0000 -111	0000 -111
9Fh	ADCON1	—	—	ADFM	—	PCFG3	PCFG2	PCFG1	PCFG0	--0- 0000	--0- 0000

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by PORTE.

2.6 MEMORY ORGANISATION :

There are three memory blocks in each of the PIC16F877 MUC's. The program memory and Data Memory have separate buses so that concurrent access can occur.

PROGRAM MEMORY ORGANISATION :

The PIC16f877 devices have a 13-bit program counter capable of addressing 8K *14 words of FLASH program memory. Accessing a location above the physically implemented address will cause a wraparound.
The RESET vector is at 0000h and the interrupt vector is at 0004h.

DATA MEMORY ORGANISTION :

The data memory is partitioned into multiple banks which contain the General Purpose Registers and the special functions Registers. Bits RP1 (STATUS<6) and RP0 (STATUS<5>) are the bank selected bits.

RP1:RP0	Banks
00	0
01	1
10	2
11	3

Each bank extends up to 7Fh (1238 bytes). The lower locations of each bank are reserved for the Special Function Registers. Above the Special Function Registers are General Purpose Registers, implemented as static RAM. All implemented banks contain special function registers. Some frequently used special function registers from one bank may be mirrored in another bank for code reduction and quicker access.

PIC16F877 REGISTER FILE MAP

Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3	File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD (1)	08h	TRISD (1)	88h		108h		188h
PORTE (1)	09h	TRISE (1)	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved(2)	18Eh
TMR1H	0Fh		8Fh	EEADRH	10Fh	Reserved(2)	18Fh
T1CON	10h		90h	General Purpose Register 16 Bytes	110h	General Purpose Register 16 Bytes	190h
TMR2	11h	SSPCON2	91h		111h		191h
T2CON	12h	PR2	92h		112h		192h
SSPBUF	13h	SSPADD	93h		113h		193h
SSPCON	14h	SSPSTAT	94h		114h		194h
CCPR1L	15h		95h		115h		195h
CCPR1H	16h		96h		116h		196h
CCP1CON	17h		97h		117h		197h
RCSTA	18h	TXSTA	98h		118h		198h
TXREG	19h	SPBRG	99h		119h		199h
RCREG	1Ah		9Ah		11Ah		19Ah
CCPR2L	1Bh		9Bh		11Bh		19Bh
CCPR2H	1Ch		9Ch		11Ch		19Ch
CCP2CON	1Dh		9Dh		11Dh		19Dh
ADRESH	1Eh	ADRESL	9Eh		11Eh		19Eh
ADCON0	1Fh	ADCON1	9Fh		11Fh		19Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h
			EFh		16Fh		1EFh
		accesses 70h-7Fh	F0h	accesses 70h-7Fh	170h	accesses 70h - 7Fh	1F0h
	7Fh		FFh		17Fh		1FFh

(shaded) Unimplemented data memory locations, read as '0'.

* Not a physical register.

Note 1: These registers are not implemented on 28-pin devices.

2: These registers are reserved, maintain these registers clear.

GENERAL PURPOSE REGISTER FILE :

The register file can be accessed either directly or indirectly through the File Selected Register (FSR). There are some Special Function Registers used by the CPU and peripheral modules for controlling the desired operation of the device. These registers are implemented as static RAM. The Special Function Registers can be classified into two sets; core (CPU) and peripheral. Those registers associated with the core functions.

2.7 INSTRUCTION SET SUMMARY :

Each PIC 16f877 instruction is a 14-bit word, divided into an OPCODE which specifies the instruction type and one or more operand which further specify the operation of the instruction. The PIC16F877 instruction set summary in Table 2.13 lists **byte-oriented, bit-oriented**, and **literal and control** operations. It shows the opcode Field descriptions.

TABLE 2.13 OPCODE FIELD DESCRIPTIONS

Field	Description
f	Register file address (0x00 to 0x7F)
W	Working register (accumulator)
b	Bit address within an 8-bit file register
k	Literal field, constant data or label
x	Don't care location (= 0 or 1) The assembler will generate code with x = 0. It is the recommended form of use for compatibility with all Microchip software tools.
d	Destination select; d = 0: store result in W, d = 1: store result in file register f. Default is d = 1
PC	Program Counter
$\overline{TO}$	Time-out bit
$\overline{PD}$	Power-down bit

For **byte-oriented** instructions, 'f' represents a file register designator and 'd' represents a destination designator. The file register designator specifies which file register is to be used by the instruction. The destination designator specified where the result of the operation is to be placed. If 'd' is zero, the result is placed in the w register. If 'd' is one, the result is placed in the file register specified in the instruction.

For **bit-oriented** instructions, 'b' represents a bit field designator which selects the number of the bit affected by the operation, which 'f' represents the address of the file in which the bits is located. For literal and control operations, 'k' represents an eight or eleven bit constant or literal value.

The instruction set is highly orthogonal and is grouped into three basic categories:

- **Byte-oriented** operations
- **Bit-oriented** operations
- **Literal and control** operations

All instructions are executed within one single instruction cycle, unless a conditional test is true or the program counter is changed as a result of an instruction. In this case, the execution takes two instruction cycles with the second cycle executed as a NOP. One instruction cycle consists of four oscillator periods. Thus, for an oscillator frequency of 4 MHz, the normal instruction execution time is 1 ms. If a conditional test is true or the program counter is changed as a result of an instruction, then the instruction execution time is 2 ms.

TABLE 2.14 16F877 INSTRUCTION SET

Mnemonic,	Operands	Description	Cycles	14-Bit Opcode MSb			LSb	Status Affected	Notes
BYTE-ORIENTED FILE REGISTER OPERATIONS									
ADDWF	f, d	Add W and f	1	00	0111	dfff	ffff	C,DC,Z	1,2
ANDWF	f, d	AND W with f	1	00	0101	dfff	ffff	Z	1,2
CLRF	f	Clear f	1	00	0001	1fff	ffff	Z	2
CLRW	-	Clear W	1	00	0001	0xxx	xxxx	Z	
COMF	f, d	Complement f	1	00	1001	dfff	ffff	Z	1,2
DECF	f, d	Decrement f	1	00	0011	dfff	ffff	Z	1,2
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00	1011	dfff	ffff		1,2,3
INCF	f, d	Increment f	1	00	1010	dfff	ffff	Z	1,2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00	1111	dfff	ffff		1,2,3
IORWF	f, d	Inclusive OR W with f	1	00	0100	dfff	ffff	Z	1,2
MOVF	f, d	Move f	1	00	1000	dfff	ffff	Z	1,2
MOVWF	f	Move W to f	1	00	0000	1fff	ffff		
NOP	-	No Operation	1	00	0000	0xx0	0000		
RLF	f, d	Rotate Left f through Carry	1	00	1101	dfff	ffff	C	1,2
RRF	f, d	Rotate Right f through Carry	1	00	1100	dfff	ffff	C	1,2
SUBWF	f, d	Subtract W from f	1	00	0010	dfff	ffff	C,DC,Z	1,2
SWAPF	f, d	Swap nibbles in f	1	00	1110	dfff	ffff		1,2
XORWF	f, d	Exclusive OR W with f	1	00	0110	dfff	ffff	Z	1,2
BIT-ORIENTED FILE REGISTER OPERATIONS									
BCF	f, b	Bit Clear f	1	01	00bb	bfff	ffff		1,2
BSF	f, b	Bit Set f	1	01	01bb	bfff	ffff		1,2
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01	10bb	bfff	ffff		3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01	11bb	bfff	ffff		3
LITERAL AND CONTROL OPERATIONS									
ADDLW	k	Add literal and W	1	11	111x	kkkk	kkkk	C,DC,Z	
ANDLW	k	AND literal with W	1	11	1001	kkkk	kkkk	Z	
CALL	k	Call subroutine	2	10	0kkk	kkkk	kkkk		
CLRWDT	-	Clear Watchdog Timer	1	00	0000	0110	0100	$\overline{TO}$,$\overline{PD}$	
GOTO	k	Go to address	2	10	1kkk	kkkk	kkkk		
IORLW	k	Inclusive OR literal with W	1	11	1000	kkkk	kkkk	Z	
MOVLW	k	Move literal to W	1	11	00xx	kkkk	kkkk		
RETFIE	-	Return from interrupt	2	00	0000	0000	1001		
RETLW	k	Return with literal in W	2	11	01xx	kkkk	kkkk		
RETURN	-	Return from Subroutine	2	00	0000	0000	1000		
SLEEP	-	Go into standby mode	1	00	0000	0110	0011	$\overline{TO}$,$\overline{PD}$	
SUBLW	k	Subtract W from literal	1	11	110x	kkkk	kkkk	C,DC,Z	
XORLW	k	Exclusive OR literal with W	1	11	1010	kkkk	kkkk	Z	

Note 1: When an I/O register is modified as a function of itself (e.g., `MOVF PORTB, 1`), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

2: If this instruction is executed on the TMR0 register (and, where applicable, d = 1), the prescaler will be cleared if assigned to the Timer0 Module.

3: If Program Counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

GENERAL FORMAT FOR INSTRUCTIONS :

Byte-oriented file register operations

13 – 8	7	6 – 0
OPCODE	d	f (FILE #)

d = 0 for destination W
d = 1 for destination f
f = 7-bit file register address

Bit-oriented file register operations

13 – 10	9 – 7	6 – 0
OPCODE	b (BIT #)	f (FILE #)

b = 3-bit bit address
f = 7-bit file register address

Literal and control operations

General

13 – 8	7 – 0
OPCODE	k (literal)

k = 8-bit immediate value

CALL and GOTO instructions only

13 – 11	10 – 0
OPCODE	k (literal)

k = 11-bit immediate value

CHAPTER 3

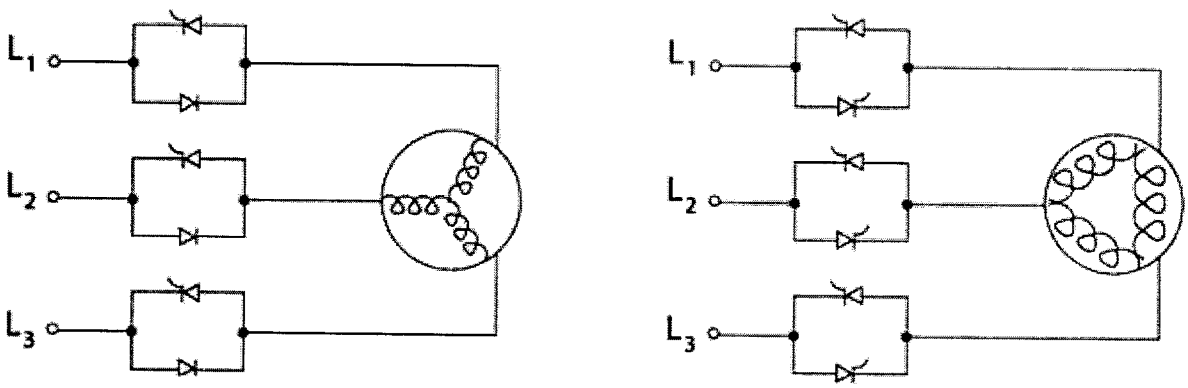
3.SOFT STARTER

3.1 PRINCIPLE OF SOFT STARTER :

To limit the starting current some large induction motors are started at reduced voltage and then have the full supply voltage reconnected when they have run up to near rated speed.

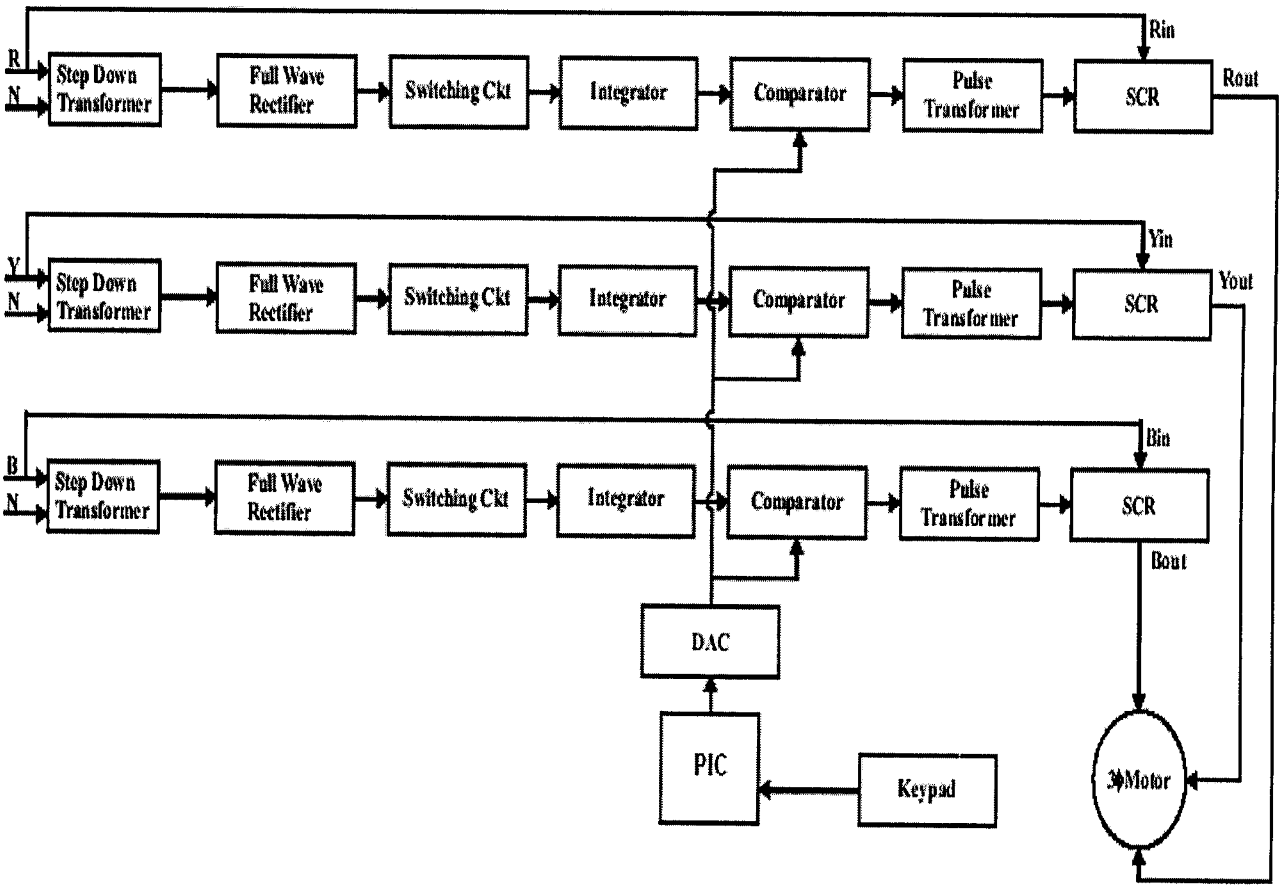
Electronic starters often referred to as 'soft start', are finding acceptance in the marine industry. Solid-state technology is employed to provide a method of starting without the current and torque surges mentioned previously. Thyristors or combination of thyristors & diodes are used to control the current flow during motor starting. The basic circuit diagrams for these two alternatives are shown in fig 3.1.

FIG 3.1 PRICIPLE OF SOFT STARTING



The electronics for controlling the firing of the thyristors is normally accommodated on a small printed circuit board within the motor controller. Although the thyristor/diode configuration is cheaper it has the disadvantage that it generates third and even harmonic currents in the motor windings, whereas the all-thyristor arrangement restricts the even harmonics.

FIG 3.2 BLOCK DIAGRAM OF SOFT STARTER CIRCUIT



3.2 OPERATION OF SOFT STARTER CIRCUIT :

With this type of starter there are normally three adjustments that have to be set to suit the drive machinery:

1). VOLTAGE RAMP :

This sets the time for the starter to achieve full voltage output. It should be noted that the ramp time is the time taken for the output voltage to reach its maximum and not for the motor to reach its full speed. If a motor is lightly loaded it may well achieve full speed before full voltage is applied.

2). CURRENT LIMIT :

This adjustment is used to prevent the starting current exceeding a preset value. As torque is proportional to the square of the current, it must be set sufficiently high that adequate torque is developed to accelerate the load from rest.

3). INITIAL FIRING ANGLE :

It is often important that a drive should start as soon as voltage is applied, e.g. if the drive is standby to a duty unit. If the initial firing angle is set too small there will be a delay in starting the drive until the voltage has been ramped to a value permitting sufficient torque to be developed to accelerate it from the rest. If the initial firing angle is set too large the load may be suddenly grabbed rather than accelerated smoothly.

TRIAC can also be used for electronic starters. However, since they have relatively low current ratings and breakdown voltages they are generally suitable only for low-current low-voltage applications.

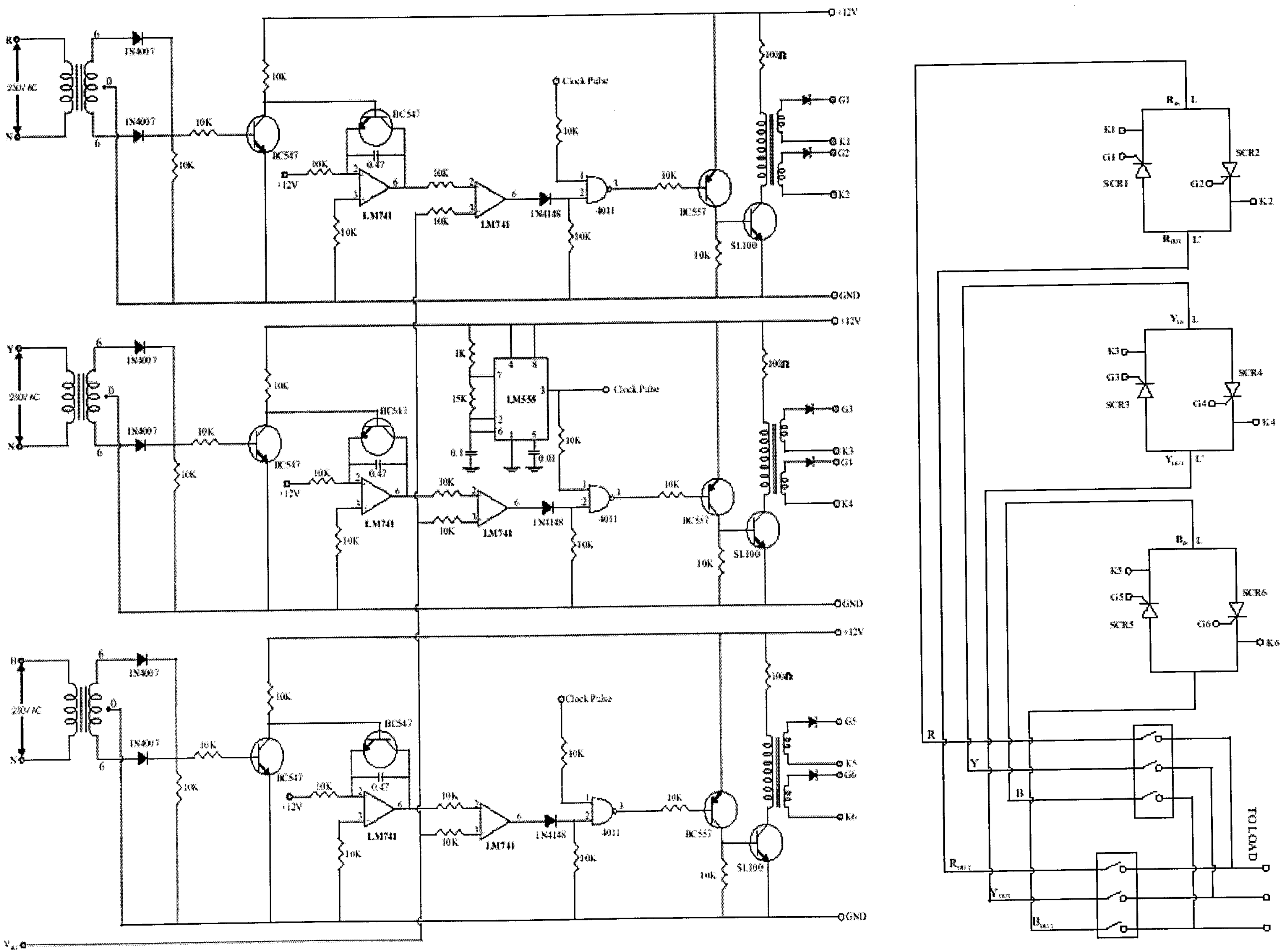


FIG 3.3 SOFT STARTER CIRCUIT

3.3 HARDWARE DECRIPTION :

3.3.1 SOFT STARTER CIRCUIT DESCRIPTION :

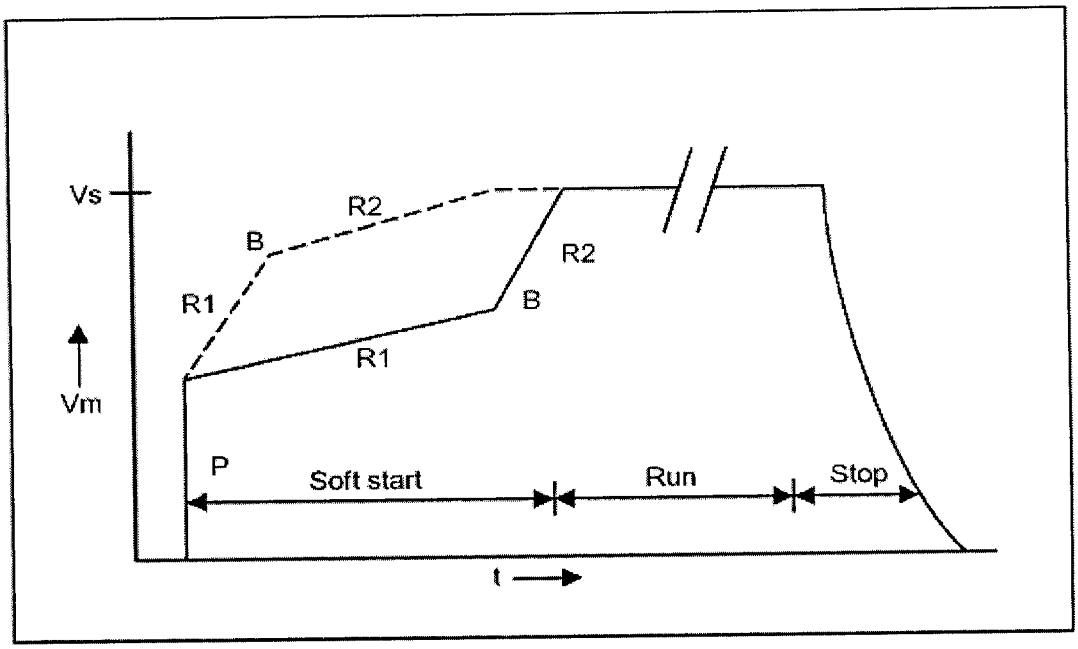
The complete circuit diagram of soft starter circuit is shown in fig 3.3. The 230V A.C voltage is converted into corresponding (15-0-15) D.C voltage by using full wave rectifier. It produces the full wave output. The output voltage obtained from the full wave rectifier is given to the switching circuit. According to the switching circuit if $V_{in} > 0.7$ then the circuit will be ON and the $V_0 = 0$. If $V_{in} < 0.7$ then the circuit will be OFF and the $V_0 = V_{cc}$. So according to the operation of switching circuit if $V_0 = V_{cc}$ then the circuit switches to Ramp Generator.

Now the Ramp generates the ramp output by charging and discharging of the capacitor. Then the comparator compares the ramp output with reference voltage from PIC through DAC 0800 (Digital to Analog Converter) and produces the required (12-0-12) output. Then the NAND Gate will activates Pulse Transformer if the output obtained from the astable multivibrator is high . Then the Pulse Transformer switches the SCR to be Triggered and the required output will be obtained.

The starting profile provided by soft starter consists of an initial pedestal level and two segment ramp, all fully adjustable as shown in the fig 3.4. The two primary starting profile controls are P and R1. P is the initial pedestal level which can be varied over the range 10-15 % of supply voltage, and is adjustable to the level necessary to overcome motor inertia. R1 is the acceleration ramp, adjustable between 2-30 seconds. B and R2 are supplementary controls for special application. In most cases, careful adjustment of P and R1 will enable good starting performance, with B at maximum and R2 at minimum.

Motor current is a function of motor voltage and speed, and can be minimized with optimum setting of P and R1, but there must always be sufficient voltage and current to overcome the load torque and allow the motor to accelerate. Soft starter comprises semiconductor switching devices controlling the voltage to motor, and the electronic control board which generates the required voltage profile for optimum starting performance.

FIG 3.4 SOFT STARTER CHARACTERISTICS



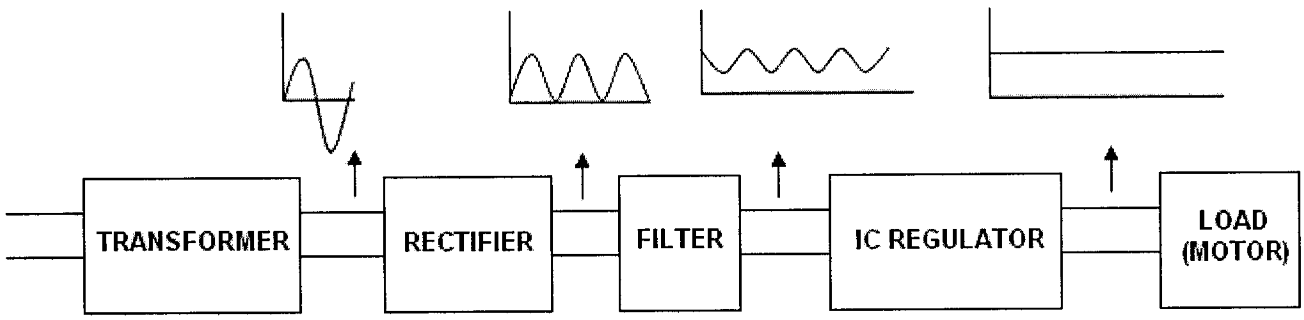
There is a pair of thyristor elements in each phase of the motor supply to give balanced full wave control of the stator voltage. Phase angle control is employed to vary the stator voltage, so during starting the motor the motor voltage and current waveform is distorted, implying high harmonic content. Thus the soft starter circuit makes the motor run smoothly.

3.3.2 POWER SUPPLIES

INTRODUCTION:

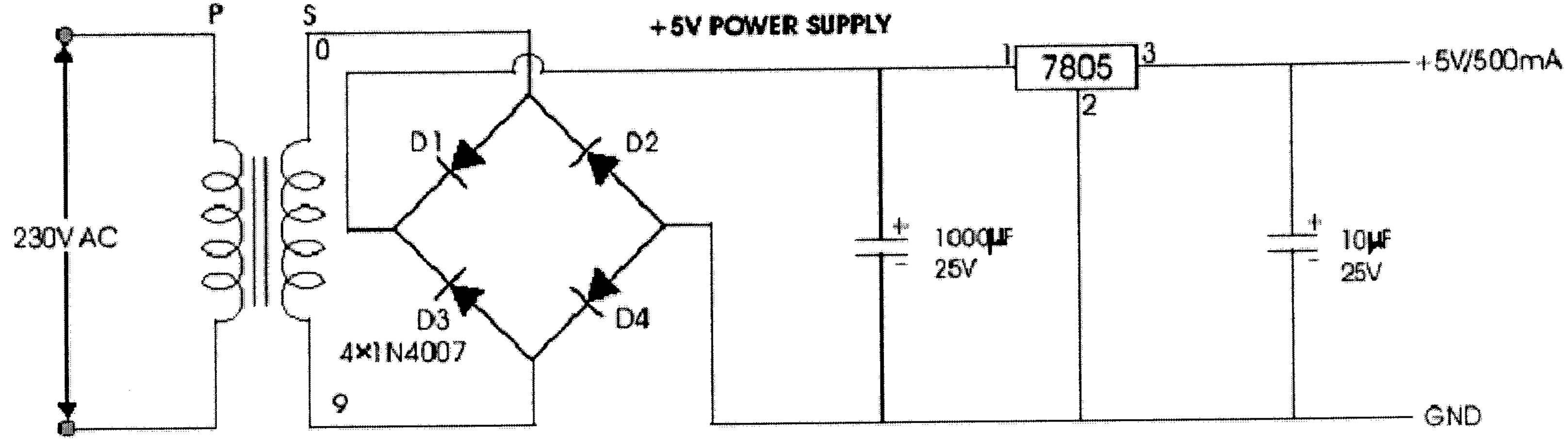
All the electronic components in the circuit are driven through the power supply circuits. The Block diagram for complete Power supply system is shown in fig 3.5A.

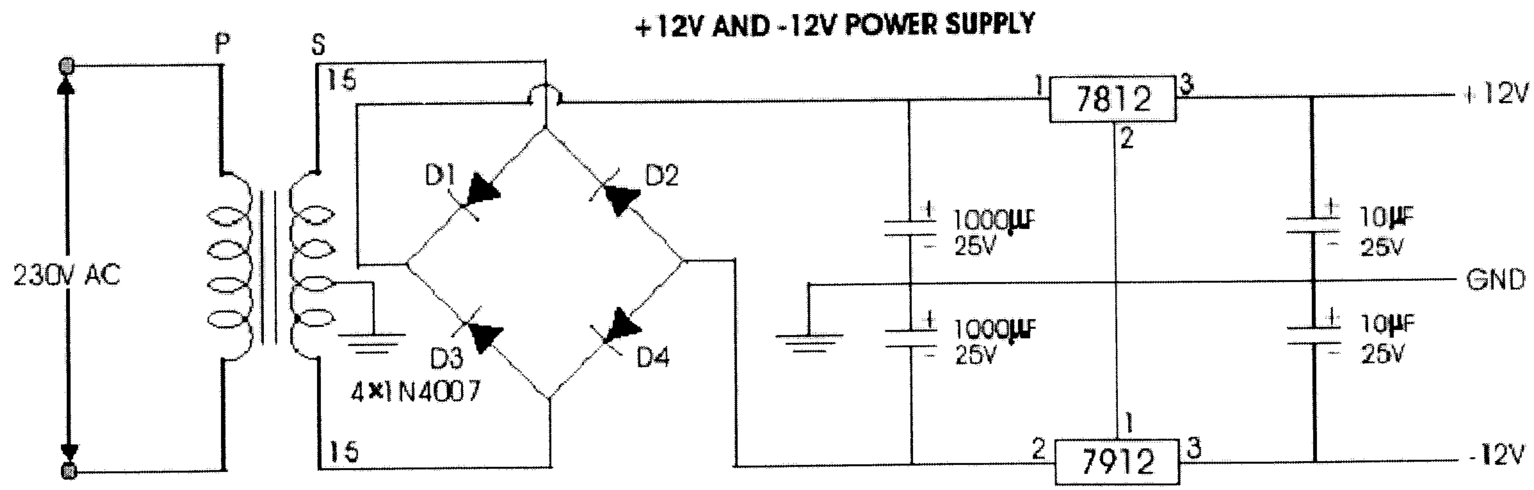
FIG 3.5A BLOCK DIAGRAM OF POWER SUPPLY CIRCUIT



For this project we use two power supply circuits. The circuit diagram of the two power supply circuits are shown in fig 3.5. The power supply circuits are built using filters, rectifiers, and then voltage regulators. Starting with an ac voltage, a steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level, and finally, regulating to obtain a desired fixed dc voltage. The regulation is usually obtained from an IC voltage regulator unit, which takes a dc voltage and provides a somewhat lower dc voltage, which remains the same even if the input dc voltage varies, or the output load connected to the dc voltage changes.

FIG 3.5 POWER SUPPLY CIRCUITS





The ac voltage, typically 230 V, is connected to a transformer, which steps that ac voltage down to the level for the desired D.C output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit can use this dc input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value even if the input dc voltage varies somewhat, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units.

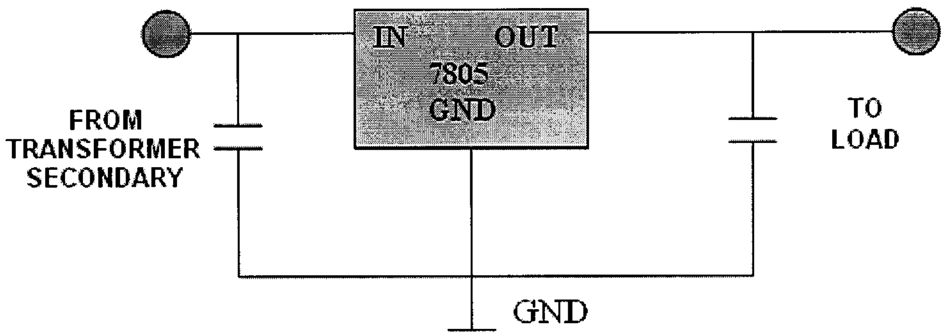
IC VOLTAGE REGULATORS:

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. Although the internal construction of the IC is somewhat different from that described for discrete voltage regulator circuits, the external operation is much the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustably set voltage. The regulators can be selected for operation with load current from hundreds of milliamperes to tens of amperes, corresponding to power ratings from milliwatts to tens of watts.

THREE-TERMINAL VOLTAGE REGULATORS :

Fig 3.6 shows the basic connection of a three-terminal voltage regulator IC to a load. The fixed voltage regulator has an unregulated dc input voltage, Vi, applied to one input terminal, a regulated output dc voltage, Vo, from a second terminal, with the third terminal connected to ground. For a selected regulator, IC device specifications list a voltage range over which the input voltage can vary to maintain a regulated output voltage over a range of load current.

FIG 3.6 FIXED POSITIVE VOLTAGE REGULATORS



The series 78 regulators provide fixed regulated voltages from 5 to 24 V. Figure 19.26 shows how one such IC, a 7812, is connected to provide voltage regulation with output from this unit of +12V dc. An unregulated input voltage Vi is filtered by capacitor C1 and connected to the IC's IN terminal.

The IC's OUT terminal provides a regulated + 12V which is filtered by capacitor C2 (mostly for any high-frequency noise). The third IC terminal is connected to ground (GND). While the input voltage may vary over some permissible voltage range, and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. A table of positive voltage regulated ICs is provided.

TABLE 3.1 POSITIVE VOLTAGE REGULATORS IN 7800 SERIES

IC Part	Output Voltage (V)	Minimum Vi (V)
7805	+5	7.3
7806	+6	8.3
7810	+10	12.5
7812	+12	14.6

3.4 DOL STARTER VS SOFT STARTER :

DOL starter usually incorporates a contactor to switch the three phase supply directly to the stator windings of the motor. This is simple, but produces high current and torque surges in the motor, accelerating it from rest to full speed very quickly. The peak starting current is more than 6 times the full load current and the starting torque more than twice the rated full load torque.

Soft starter is a reduced voltage starter using semiconductor switching devices to control the voltage to the motor. The starting current and torque are correspondingly reduced and the acceleration time is extended.

FIG 3.7 DOL vs SOFT STARTER CHARACTERISTICS

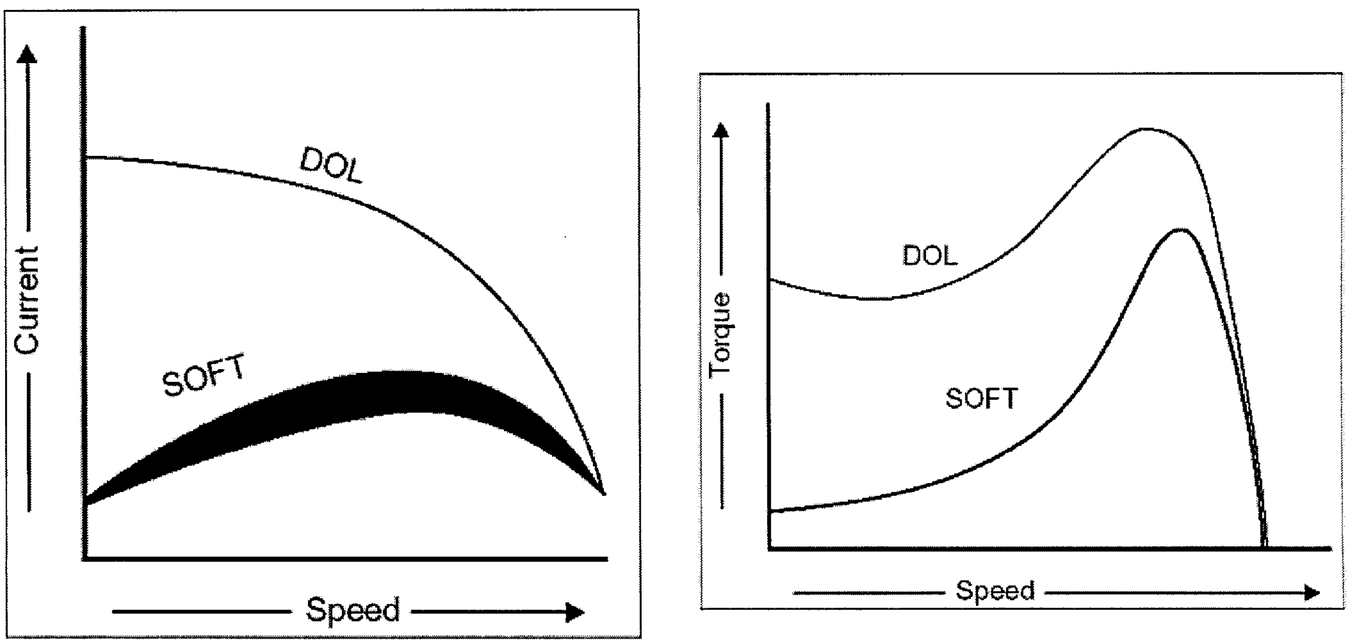


Fig 3.7 compares the typical DOL starting current and torque with that of the soft starter. This shows that soft starting method is more efficient method of starting compared to other methods.

3.5 SPECIAL FEATURES :

The proper method of starting motors can result in reduced down time & increased productivity. Listed below are the examples which depict the Maintenance Manager's nightmares for not opting for the right starting methods –

- Breakage of conveyor belts during starting or stopping of a process.
- Higher Peak Demand charges from the Utility.
- Poor Energy Utilization due to machines being over designed for peak torque.
- Voltage sags on the power system during starting of a big motor.
- Nuisance circuit breaker tripping or fuse blowing during starting of large motors.
- Excessive maintenance due to wear & tear of electro-mechanical components.
- Problems related to Water Hammering phenomenon.

Soft starters are ideal for meeting utility restrictions for limiting the inrush current while starting high horse power motors. Soft starters provides a multitude of benefits for process & machine applications due to their smooth output voltage ramp, torque limiting & overriding adjustable current limit feature. Typical motor loads that are good candidates for soft starters include centrifugal pump, fans, batch centrifuges, unloaded rock crusher, unloaded compressors & lightly loaded compressors.

Most soft starters use voltage control to limit the motor starting current & torque by continuously ramping the applied voltage when starting & stopping.

TABLE 3.2 FLC's FOR NORMAL MOTORS

kW	HP	230V	240V	400V	415V	440V	600V
.75	1	3.3	3.1	2	2	1.67	1.22
1.1	1.5	4.9	4.1	2.6	2.5	2.26	1.66
1.5	2	6.2	5.6	3.5	3.5	3.03	2.22
2.2	3	8.7	7.9	5	5	4.31	3.16
3	4	11.6	10.6	6.6	6.5	5.8	4.25
3.7	5	14.2	13	8.2	7.5	7.1	5.2
4	5.5	15.3	14	8.5	8.4	7.6	5.6
5.5	7.5	20.6	18.9	11.5	11	10.3	7.5
7.5	10	27.4	24.8	15.5	14	13.5	9.9
9	12.5	32	29.3	18.3	17	15.8	11.6
11	15	39.2	35.3	22	21	19.3	14.1
15	20	52.6	48.2	30	28	26.3	19.3
18.5	25	64.9	58.7	37	35	32	23.5
20	27	69.3	63.4	40	37	34.6	25.4
22	30	75.2	68	44	40	37.1	27.2
30	40	101	92.7	60	55	50.1	37.1
37	50	124	114	72	66	61.9	45.4
45	60	150	136	85	80	73.9	54.2
55	75	181	166	105	96	90.3	66.2
75	100	245	226	140	135	123	90.3
90	125	292	268	170	165	146	107
100	136	325	297	188	182	162	119
110	150	358	327	205	200	178	131
129	175	420	384	242	230	209	153
132	180	425	393	245	242	214	157
147	200	472	432	273	260	236	173
160	220	502	471	295	280	256	188
180	245	578	530	333	320	289	212
184	250	590	541	340	325	295	217
200	270	626	589	370	340	321	235
220	300	700	647	408	385	353	260
250	340	803	736	460	425	401	295
257	350	826	756	475	450	412	302
295	400	948	868	546	500	473	348
315	430	990	927	580	535	505	370
355	480	1080	1010	636	580	549	405
400	545	1250	1130	710	650	611	450
450	610	1410	1270	800	740	688	508
475	645	1490	1340	850	780	730	540
500	680	1570	1420	890	830	770	565
560	760	1750	1580	1000	920	860	630

NOTE : Typical Full load current (FLC) for 1500rpm motors running on 50Hz supply are liste in table 3.2. Full load current ratings vary between motor manufacturers, pole configuration etc.

CHAPTER 4

4. MOTOR MONITORING SYSTEM

4.1 INTRODUCTION :

The development of technology has contributed machine-man interfacing and utilization of computers. Doing the same type of work repeatedly for days together cause strain and fatigue for humans. The enhanced facilities using computers has reduced the work burden on the human beings and also reduced manual operations.

Motor monitoring is one of the essential requirements in college laboratories and industrial testing. For this individual meter are used for measurement of various parameters. Due to this size and cost is more and also human errors are introduced when readings are taken. The errors are avoided by constructing all the individual meters into single one instrument using microcontroller.

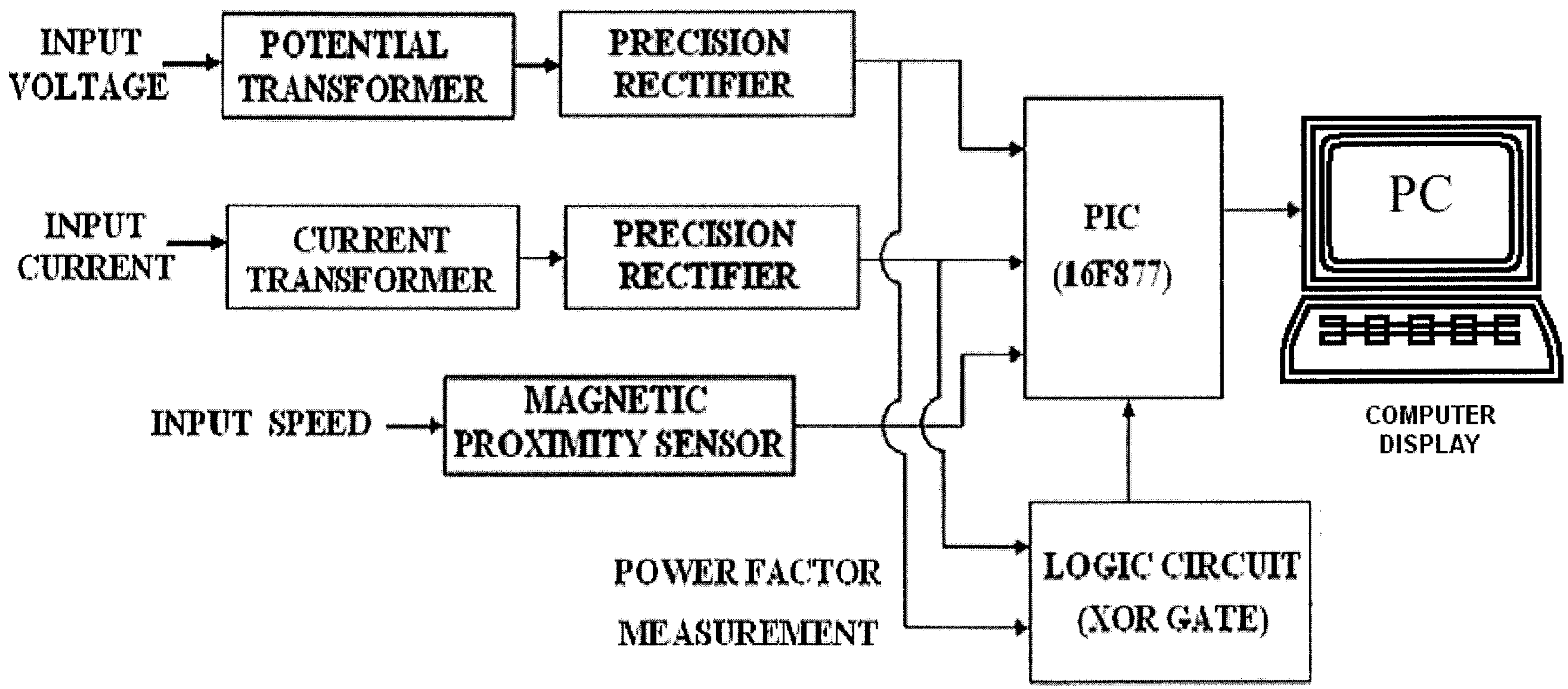
MOITORING SYSTEM :

Our project envisages monitoring of voltage, current, speed and power factor of three phase induction motor. We have chosen PIC microcontroller to monitor the above four parameters. The inbuilt ADC in PIC can be used for analog to digital conversion process, which reduces additional hardware requirements. The voltage and current are stepped down to required level through potential transformer & current transformer respectively.

For measurement of speed, the magnetic proximity sensor converts the number of revolutions into pulses. The pulses are again converted into voltage and given as input to PIC. For measurement of power factor, the output from two precision rectifiers (current & voltage) is given to a logic circuit. The logic circuit performs XOR operation and the result is given as input to PIC.

The Block diagram representation of Motor monitoring system is shown in the figure 4.1.

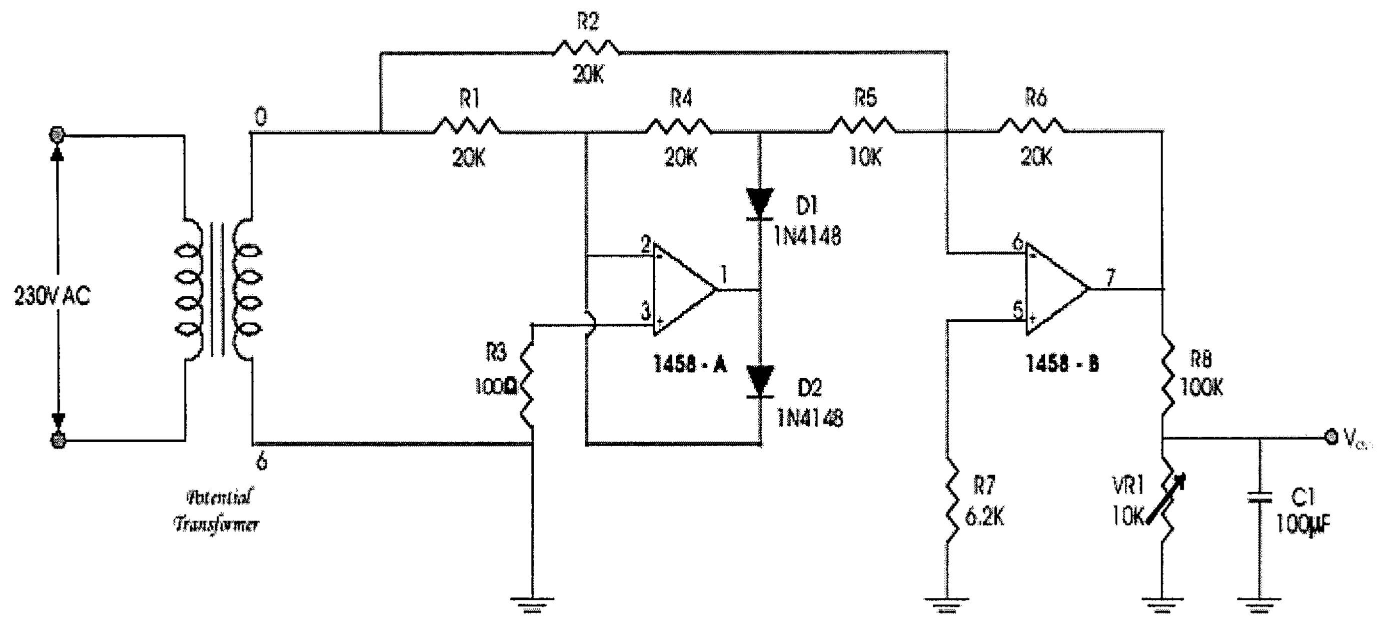
FIG 4.1 BLOCK DIAGRAM REPRESENTATION OF MONITORING SYSTEM



4.2 MEASUREMENT OF VOLTAGE :

In this section, voltage input from the motor is measured. The circuit diagram for voltage measurement is shown in fig 4.2.

FIG 4.2 VOLTAGE MEASUREMENT CIRCUIT

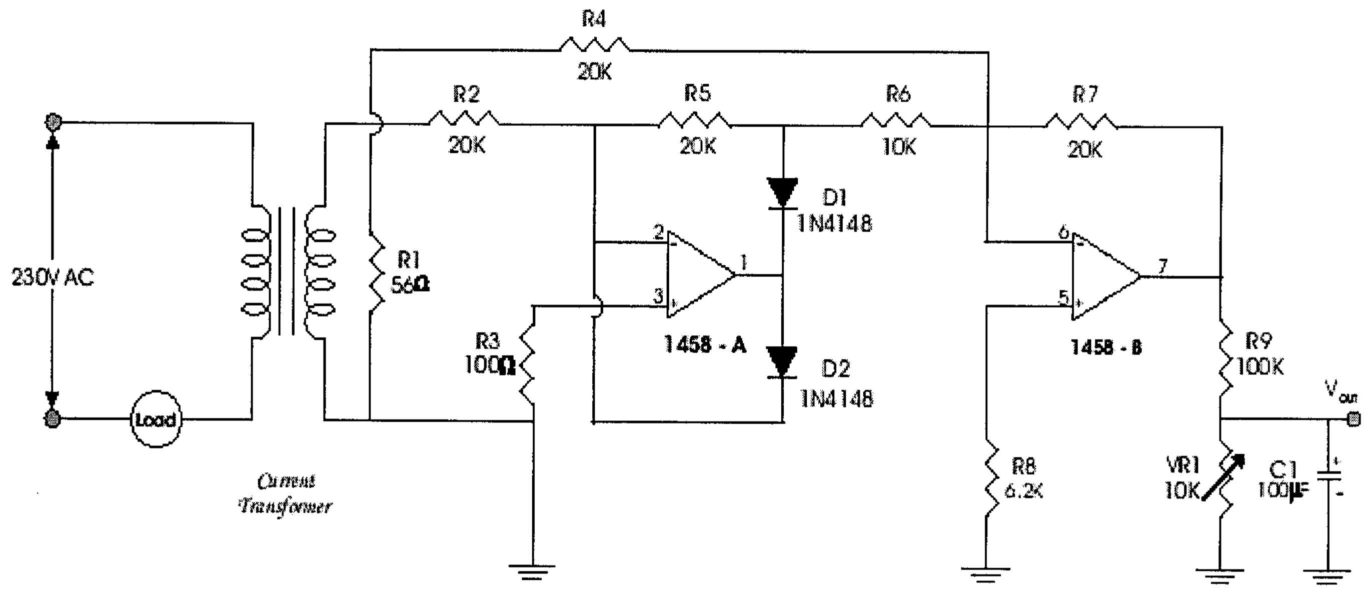


The circuit consists of a 230/12V step down potential transformer, rectifier circuit, capacitor filter circuit and variable potentiometer. The voltage from motor is given to step down transformer, where the voltage is reduced to 12V. the rectifier circuit is connected to across the secondary of the potential transformer. During the positive half cycle, the op-amp 1458 A functions and during the negative half cycle, the op-amp 1458 B functions. Thus the output voltage is unidirectional, i.e the A.C voltage is converted to D.C voltage. In order to avoid the ripple content in the D.C output, capacitor filter circuit is used. The filtered output voltage is available across variable potentiometer which is given as input to PIC.

4.3 MEASUREMENT OF CURRENT :

In this section, current input from the motor is measured. The circuit diagram for voltage measurement is shown in fig 4.3.

FIG 4.3 CURRENT MEASUREMENT CIRCUIT

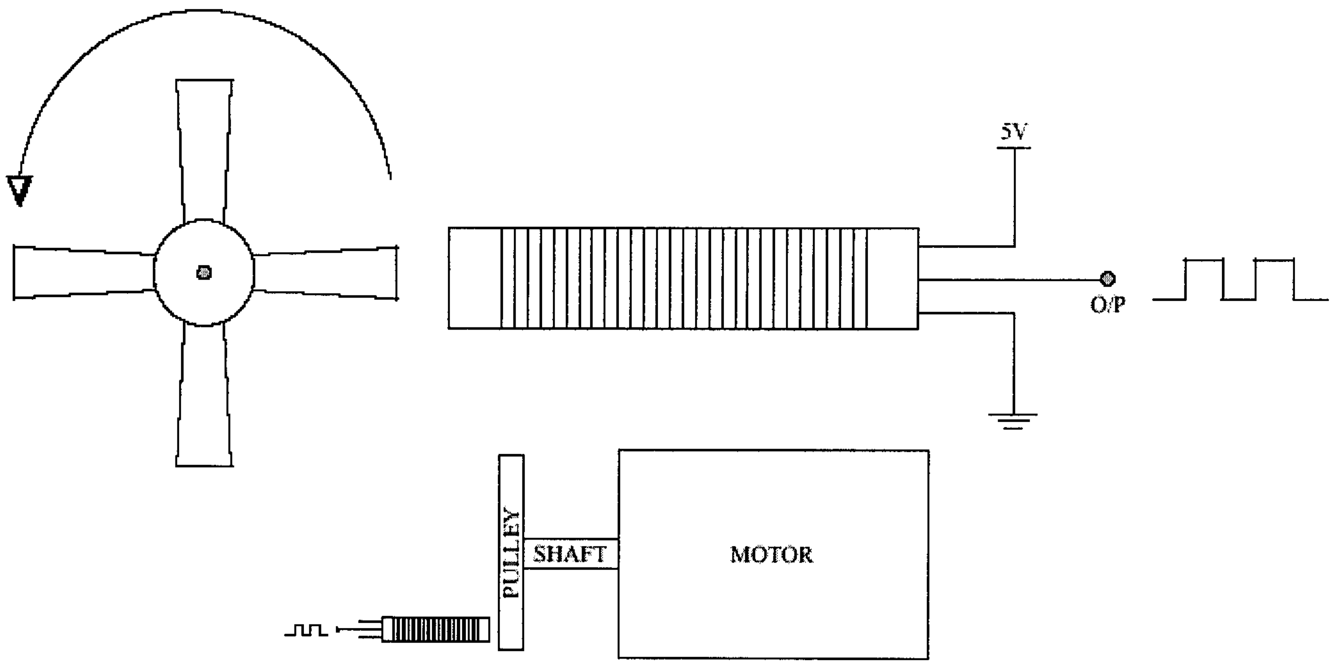


The circuit consists of a 6A/600mA step down current transformer, rectifier circuit, capacitor filter circuit and variable potentiometer. The current from motor is given to step down transformer, where the current is reduced. The rectifier circuit is connected to across the secondary of the current transformer. During the positive half cycle, the op-amp 1458 A functions and during the negative half cycle, the op-amp 1458 B functions. Thus the output current is unidirectional, i.e the alternating current is converted to direct current. In order to avoid the ripple content in the D.C output, capacitor filter circuit is used. The filtered output current is available across variable potentiometer which is given as input to PIC.

4.4 MEASUREMENT OF SPEED :

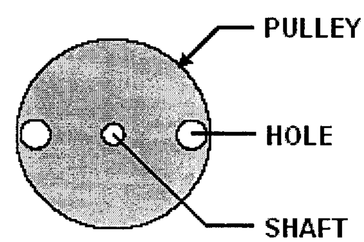
In this section, speed of the motor is measured. The circuit diagram for voltage measurement is shown in fig 4.4.

FIG 4.4 SPEED MEASUREMENT CIRCUIT



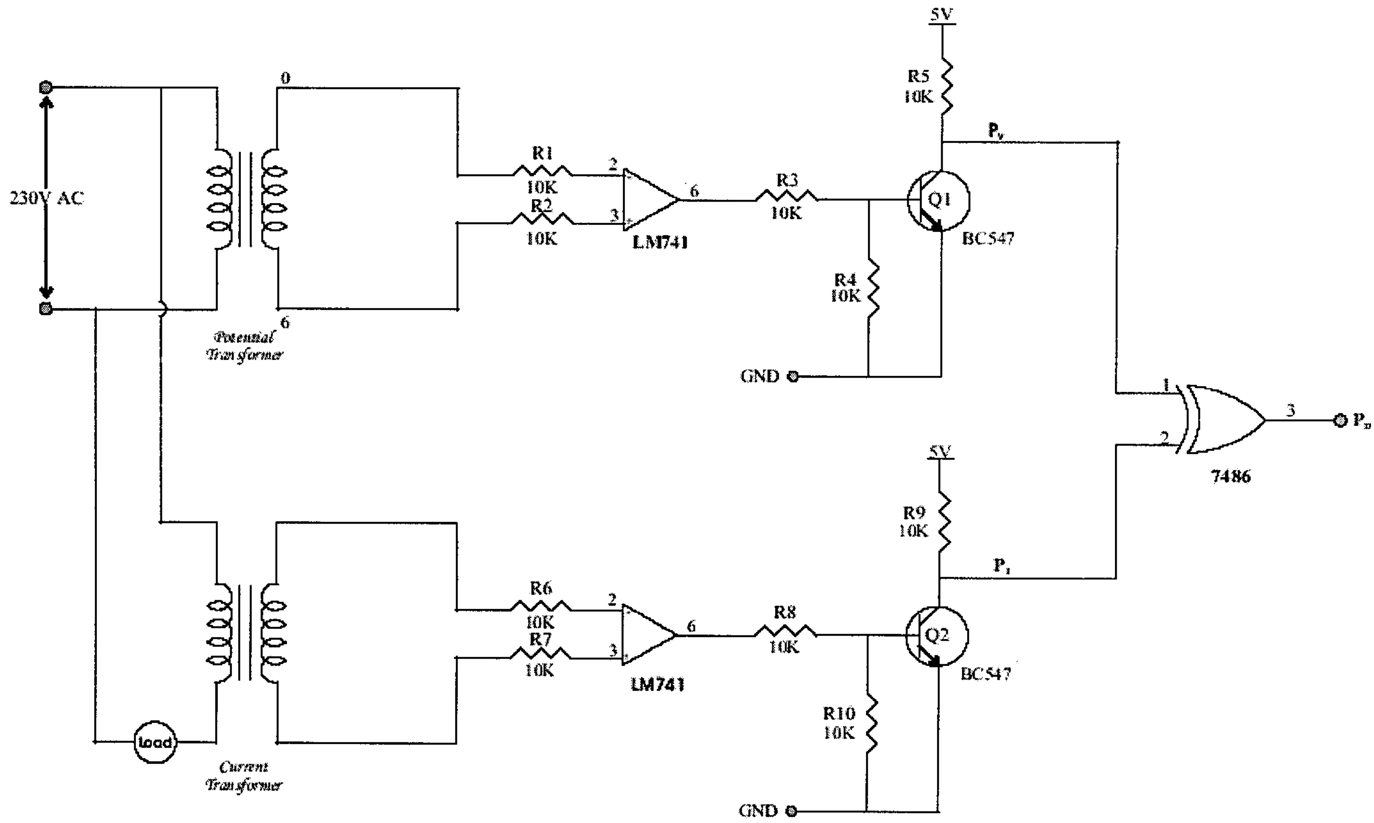
The circuit consists of a Magnetic Proximity Sensor, which includes inbuilt frequency to voltage converter. The proximity sensor produces a magnetic field around 2cm in front of it. A provision is fitted with the shaft of the motor so that it cuts the magnetic field (produced by sensor) at the end of each revolution. The proximity sensor converts the number of revolutions into pulses. Further those pulses are converted into voltage linearly and is given as input to PIC. A sample arrangement to cut the magnetic field at end of each revolution is shown in fig 4.4b

FIG 4.4b SAMPLE ARRANGEMENT
(HOLE DIA > SENSOR DIA)



4.5 MEAUREMENT OF POWER FACTOR :

FIG 4.5 POWER FACTOR MEASUREMENT CIRCUIT



The difference in phase angle between the voltage and current can be calculate by using the zero-cross detector. The sinusoidal waveforms of voltage and current is given to the zero-cross detector, the output will be the corresponding square wave. These signals are then given to an XOR Gate with one of the input inverted (say for corresponding voltage signal of current).

The XOR gate will give the output when both the inputs are high. When one of the inputs to the Gate is inverted, then the gate will be conducting for the moment when the inverted input is low and the other input is high. We can calculate this time period through the timer facility available in PIC. From that we can calculate the power factor using the pre calculated table. Say for example if the conduction period of the XOR gate is 700 μsec then the power factor will be 0.7.

4.6 HARDWARE DESCRIPTION :

The monitoring system functions only after the motor has attained its rated voltage. The relay circuit is set such that only when it receives the signal from PIC it gets energized and operates the contactors. During soft starting contactor 1 will be closed while contactor 2 remains opened. After the motor has attained its rated voltage contactor 1 opens and contactor 2 gets closed which connects monitoring system with motor. The relay circuit receives the signals from the pins RC4 & RC5. The device clock, i.e., a crystal oscillator of 4MHz is connected between the pins 13 & 14. The device clock is required for the device to execute instructions and for the peripherals to function.

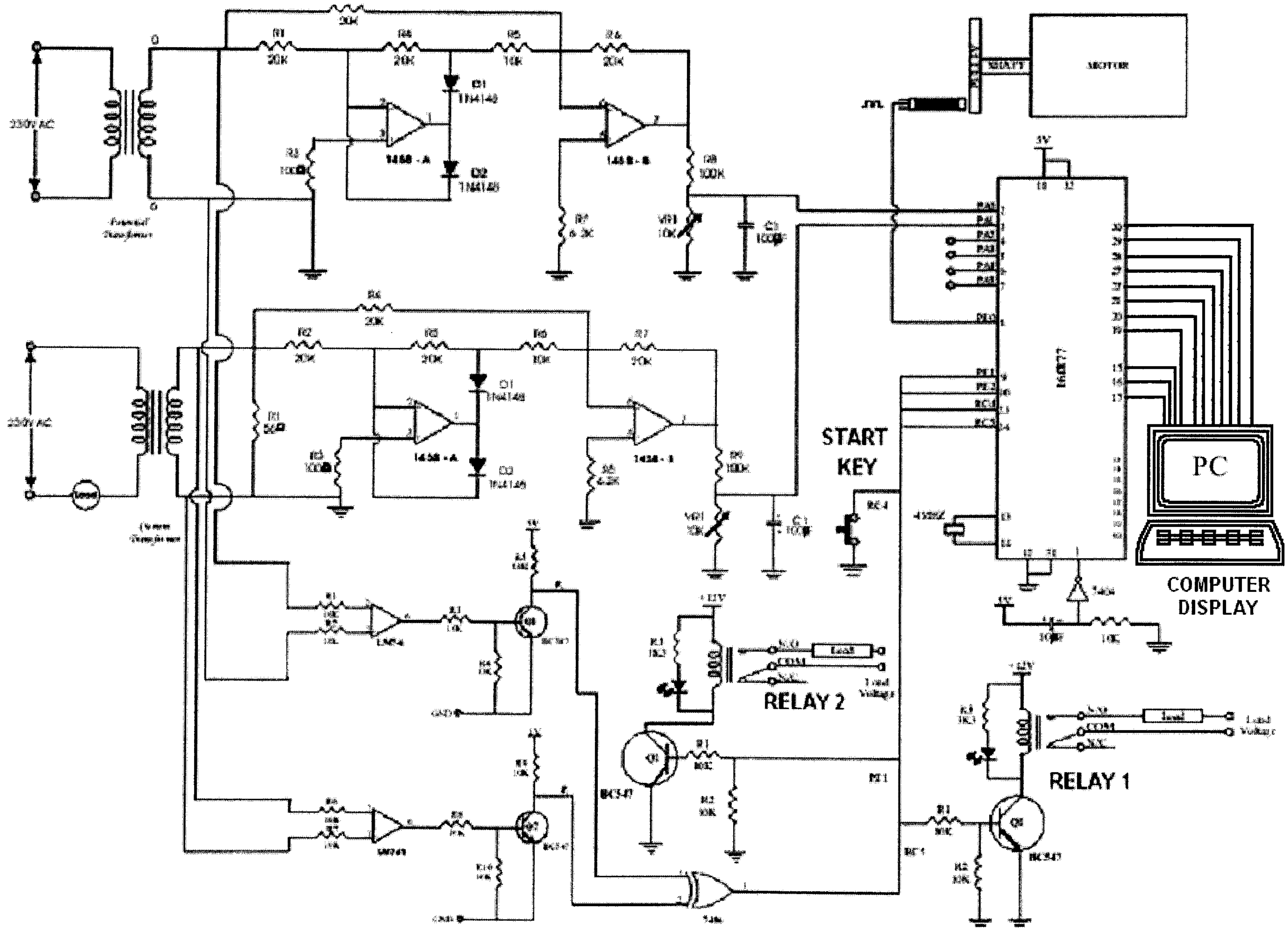
The complete circuit diagram of the motor monitoring system is shown in the fig 4.6. It consists of four main sections, namely

- Voltage measuring circuit board
- Current measuring circuit board
- Proximity sensor circuit board
- PIC circuit board

Voltage & Current measuring circuits produce D.C analog output, which is given to the pins PA0 and PA1 (2 & 3) of the PIC (16F877). Proximity sensor circuit board senses the speed and converts into voltage of proportional value. This output is given to the pin PE0. The output from voltage & current measuring circuits are given to a logic circuit. The logic circuit performs XOR gate operation & returns a value which is given to the pin PE1. XOR operation is done through IC 7486.

All these values are in analog form. The inbuilt ADC of the PIC converts all these analog values into digital form.

FIG 4.6 MONITORING SYSTEM CIRCUIT



The digital output is obtained through PORT D. The output is taken from the pins RD0 to RD7 and interfaced with COM 1 port in CPU of the computer. During the run time, if there is any variation in load, the corresponding variation in the parameters can be observed in the monitor.

FABRICATION OF PROTO TYPE MODEL & TESTING :

This overall kit for three phase induction motor serves for two main purposes. First, it makes the machine to start and run smoothly. Second, it monitors some parameters (voltage, current, speed & power factor) of the machine during the runtime through digital computer display.

In soft starter circuit, we have used SCR's rated 25A & hence it suits for three phase induction motors rated up to 20 H.P. In monitoring system, we have used potential transformer rated 230/6V and current transformer rated 15/1A. Hence we can measure voltage & current according to the above specified values.

We tested the complete circuit using a 1 H.P three phase induction motor. At first, we had a problem in power factor monitoring. We observed the value exceeding the prescribed limit. When analyzing this problem, we found it was related with programming in PIC.

For calculating power factor, we converted time period into angle using a suitable ratio. But it didn't suit for our system. Hence we made a pre calculated table and modified the program according to it. Say for example, if the conduction period of XOR gate is 700 microseconds, then the power factor will be 0.7.

The above modification made our project function successfully. During the final testing, after overcoming all the problems, we achieved our target.

CHAPTER 5

5. SOFTWARE SECTION

5.1 CODING :

```
#include<pic.h>        //Program for 3 phase soft starter
#include<math.h>

static bit  rs  @((unsigned) &PORTC*8+0);
static bit  rw  @((unsigned) &PORTC*8+1);
static bit  en  @((unsigned) &PORTC*8+2);

static bit  input @((unsigned) &PORTE*8+0);    //PF input
static bit  pulse @((unsigned) &PORTE*8+1);    //SPEED input
static bit  key1  @((unsigned) &PORTE*8+2);

static bit  relay1 @((unsigned) &PORTC*8+5);    //o/p pins
static bit  relay2 @((unsigned) &PORTC*8+4);

void lcd_init();
void command(unsigned char);
void lcd_disp(unsigned char);
void lcd_condis(const unsigned char*,unsigned int);
void hex_dec(unsigned char);
void hex_dec_cur(unsigned char);
void hex_dec_pf(unsigned char);
void hex_dec_rpm(unsigned int);

void ser_txn(unsigned char);
void ser_contxn(const unsigned char*,unsigned int);

void delay(unsigned int);

unsigned char count,b,pf;
unsigned char i,h,hr,t,o,vol,cur;
unsigned char dac,l,hi;
float x,y;
unsigned int s,rps,rpm,th,thr;
bit k1,j,p,fac;

void interrupt  timer1(void)
{
```

```
if(TMR1IF==1 && fac==1)     //for power factor cal
{
 TMR1ON=0;
 TMR1IF=0;
 TRISC=0x00;

 count++;

 TMR1H=0xfc;
 TMR1L=0x25;
 TMR1ON=1;
}
else if(TMR1IF==1 && fac==0)     //for time cal
{
 TMR1ON=0;
 b++;
 if(b==15)       //for 1 sec
 {
  b=0;
  s++;
  j=1;
 }
 TMR1IF=0;
 TMR1ON=1;
}
}

main()
{
 ADCON1=0x02;
 TRISA=0x3f;
 dac=0x00;
 TRISD=0x00;
 TRISC=0x00;
 TRISB=0x00;
 TRISE=0x07;

 lcd_init();
 lcd_condis("  THREE PHASE   ",16);
 command(0xc0);
 lcd_condis("  SOFT STARTER  ",16);
```

```
delay(50000);
command(0x01);
GIE=1;
PEIE=1;
TMR1IE=1;
TMR1L=0x00;
TMR1H=0x00;

relay1=relay2=0;
k1=0;

while(1)
{
 TRISE=0x07;

 if(key1==0 && k1==0) k1=1;
 if(key1==1 && k1==1)
 {
  k1=0;
  while(1)
  {
   relay1=1;
   dac++;
   PORTB=dac;
   command(0x80);
   lcd_condis("dac:",4);
   hex_dec(dac);
   delay(1500);
   if(dac==0xe6)
   {
    relay1=0;
    relay2=1;
    command(0x01);
    goto jmp;
   }
  }

  while(1)
  {
jmp:
   relay2=1;
```

```
ADCON0=0x00;
ADON=1;
delay(100);
ADCON0=0x05;
while(ADCON0!=0x01);
vol=ADRESH;

command(0x80);
lcd_condis("V:",2);
hex_dec(vol);

ser_txn(' ');
ser_contxn("Voltage:",8);
ser_txn(h+0x30);
ser_txn(t+0x30);
ser_txn(o+0x30);
ser_contxn("         ",9);

ADON=0;
ADCON0=0x08;
ADON=1;
delay(100);
ADCON0=0x0d;
while(ADCON0!=0x09);
cur=ADRESH;

command(0x88);
lcd_condis("I:",2);
hex_dec_cur(cur);

ser_contxn("Current:",8);
ser_txn(h+0x30);
ser_txn(t+0x30);
ser_txn('.');
ser_txn(o+0x30);
ser_contxn("         ",9);

TMR1ON=0;
hi=TMR1H;
l=TMR1L;
```

```
TMR1H=0xfc;
TMR1L=0x25;
while(input==0);
TMR1ON=1;
fac=1;
while(input==1);
fac=0;

TMR1L=l;
TMR1H=hi;

x=count*1.8;
x=x*3.14;
x=x/180;
y=cos(x);
y=y*1000;
pf=y;
pf=y/10;

command(0xc0);
lcd_condis("PF:",3);
hex_dec_pf(pf);
count=0;

ser_contxn("PF:",3);
ser_txn(h+0x30);
ser_txn('.');
ser_txn(t+0x30);
ser_txn(o+0x30);
ser_contxn("         ",9);

rps=rpm=0;
b=j=0;
while(!j)
{
 TRISE=0x07;
 if(pulse==0 && p==0) p=1;
 if(pulse==1 && p==1)
 {
  p=0;
  rps++;
```

```
   }
  }
  rpm=rps*60;
  command(0xc8);
  lcd_condis("SP:",3);
  hex_dec_rpm(rpm);

  ser_contxn("Speed:",6);
  ser_txn(th+0x30);
  ser_txn(h+0x30);
  ser_txn(t+0x30);
  ser_txn(o+0x30);
  ser_contxn("         ",9);
 }
 }
}
}

void lcd_init()
{
 TRISC=0x00;
 TRISD=0;
 command(0x38);//to select function set
 command(0x06);//entry mode set
 command(0x0c);//display on
 command(0x01);//clear display
}

void command(unsigned char com)
{
  PORTD=com;
  en=1;
  rs=rw=0;
  delay(125);
  en=0;
  delay(125);
}

void lcd_disp(unsigned char lr)
{
 PORTD=lr;
```

```
 en=1;
 rs=1;
 rw=0;
 delay(125);
 en=0;
 delay(125);
}

void lcd_condis(const unsigned char *word,unsigned int n)
{
 for(i=0;i<n;i++)
 {
  lcd_disp(word[i]);
 }
}

void hex_dec(unsigned char val)
{
 h=val/100;
 hr=val%100;
 t=hr/10;
 o=hr%10;

 lcd_disp(h+0x30);
 lcd_disp(t+0x30);
 lcd_disp(o+0x30);
}

void hex_dec_cur(unsigned char val)
{
 h=val/100;
 hr=val%100;
 t=hr/10;
 o=hr%10;

 lcd_disp(h+0x30);
 lcd_disp(t+0x30);
 lcd_disp('.');
 lcd_disp(o+0x30);
}
```

```
void hex_dec_pf(unsigned char val)
{
 h=val/100;
 hr=val%100;
 t=hr/10;
 o=hr%10;

 lcd_disp(h+0x30);
 lcd_disp('.');
 lcd_disp(t+0x30);
 lcd_disp(o+0x30);
}

void hex_dec_rpm(unsigned int val)
{
 th=val/1000;
 thr=val%1000;
 h=thr/100;
 hr=thr%100;
 t=hr/10;
 o=hr%10;

 lcd_disp(th+0x30);
 lcd_disp(h+0x30);
 lcd_disp(t+0x30);
 lcd_disp(o+0x30);
}

void ser_txn(unsigned char te)
{
  SPBRG=51;        //for 1.2 kb baud rate
  BRGH=0;          //for low baud rate
  SYNC=0;          //asynchronous mode
  SPEN=1;          //Enable the serial port
  TXEN=1;          //enable TXion
  TXREG=te;
  delay(2500);
  TXIF=0;
}
```

```
void ser_contxn(const unsigned char *dat,unsigned int m)
{
 unsigned int j;

 for(j=0;j<m;j++)
 {
  TXREG=dat[j];
  delay(1500);
 }
}

void delay(unsigned int del)
{
 while(del--);
}
```

5.2 FLOW CHART

FIG 5.1 FLOW CHART FOR SOFT STARTING OPERATION

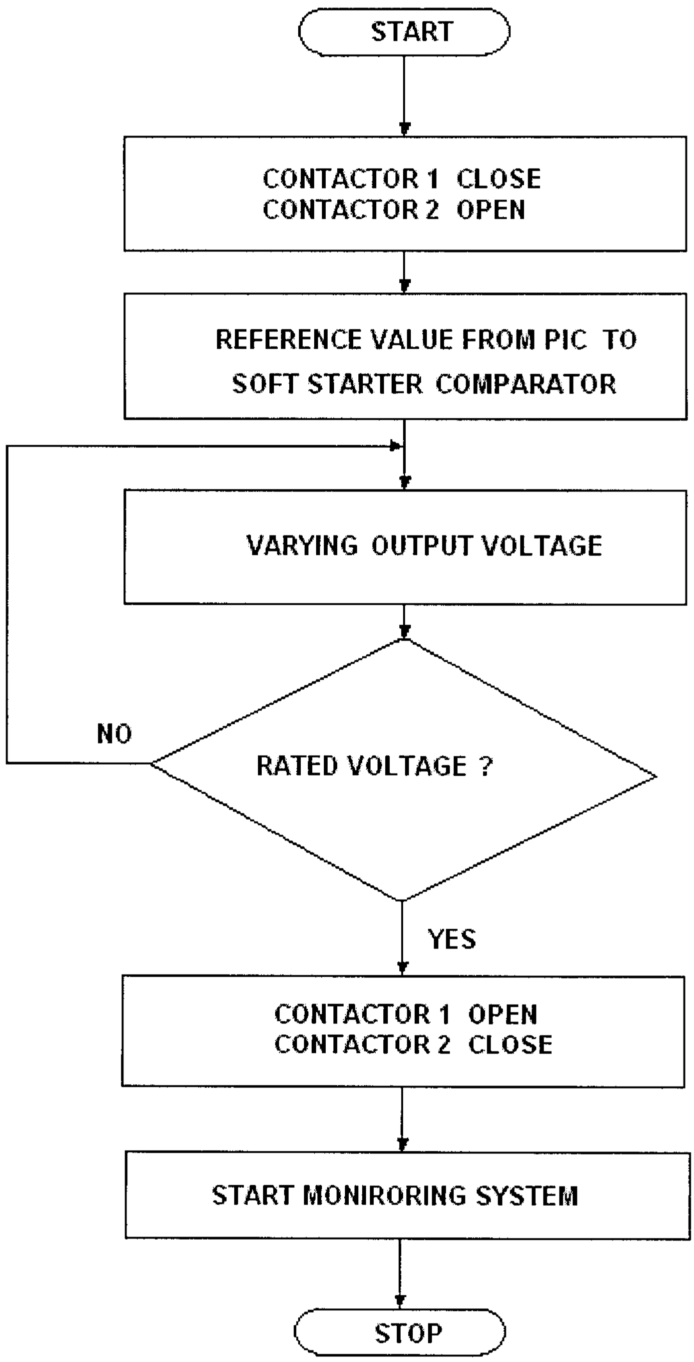
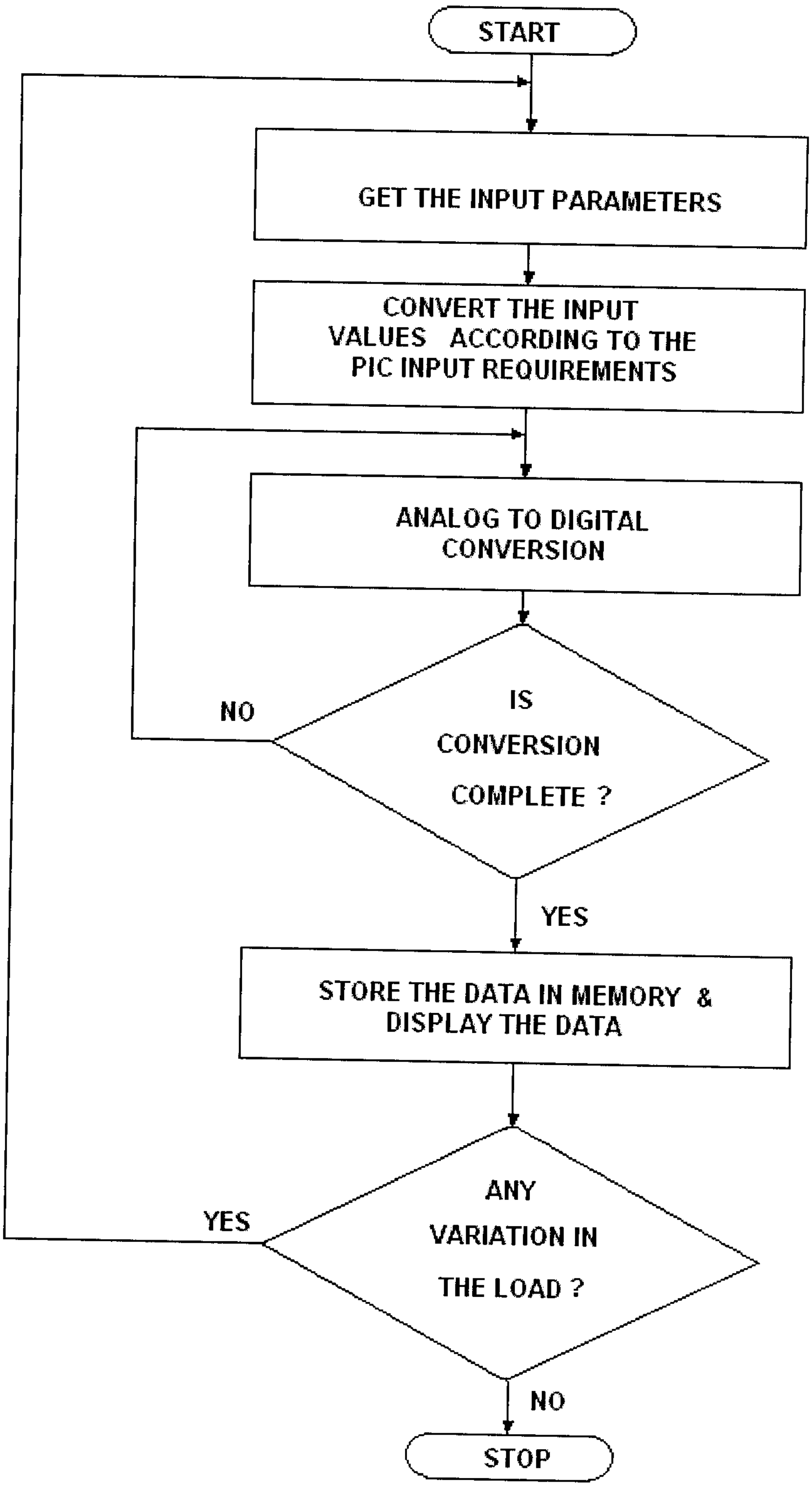


FIG 5.2 FLOW CHART FOR MONITORING SYSTEM



APPLICATIONS

- This project is very much useful in college laboratories, where various tests on the motor are performed. At each time connecting individual meters may cause strain & fatigue. Using this kit the parameters are displayed in digital form, which helps in easy observations. Since embedded technology is used, the size of the kit is small and also more accurate.

- This kit can be applied to large rating of motors where the soft starting operation will be more efficient compared to other type of starting methods. Here we have mostly used electronic components & hence less power consumption. It also avoids the problem of sparking that occurs frequently in starting of large rating motors.

- It can also be applied to low rating motors which also requires reduced voltage starting.

- This project is also useful in manufacturing industries. In manufacturing industries, motor should be kept under testing conditions, for that we need a test rig, that should monitor and it should give alarm for the critical conditions of those parameters. So this particular project is very essential for manufacturing industries.

- This kit is useful in applications like compressors, material handling equipments, pumps, conveyors and other applications where the motor is partially loaded or unloaded for extended periods of time.

- This kit will be more helpful in Research & Development departments by reducing the manual operations (wire connections) that has to be done by the developer during the experimentation.

FUTURE ENHANCEMENTS

This project can be enhanced with power factor control by replacing a microcontroller with more number of ports. Power factor correction can be done either using capacitor banks or by using thyristor control. The monitoring system can be enhanced by displaying the characteristics in graphical format, by including some additional programs. Also various other parameters such as frequency, temperature etc can be monitored according to the application requirements.

The previous generation soft starter requires an external feedback signal to maintain constant acceleration torque or requires a point to point study of load torque characteristics before judging the compatibility of the soft starter with the driven load. The soft starter using ATS 46 microprocessor can integrate the patented design of Torque Control into the soft starter. The logic based torque control system using a time proven control algorithm to maintain constant accelerating & decelerating torque. It can also be designed with own built-in self-protection and fault detection.

An advanced electronic motor overload protection can be set to tripping classes. It is also possible to set a dual overload protection so that one tripping class applies during the start-up and another one during continuous running. If required, underload protection can also be set. The starter can be enhanced with protection against locked rotor, phase imbalance, phase reversal and high current.

CONCLUSION

A complete testing equipment which could aid Three Phase Induction motor, using the combination of electronic components and embedded technology has been fabricated and tested. This overall kit for three phase induction motor serves for two main purposes. First, it makes the machine to start and run smoothly. Second, it monitors various parameters of the machine during the run time through digital computer display without any errors.

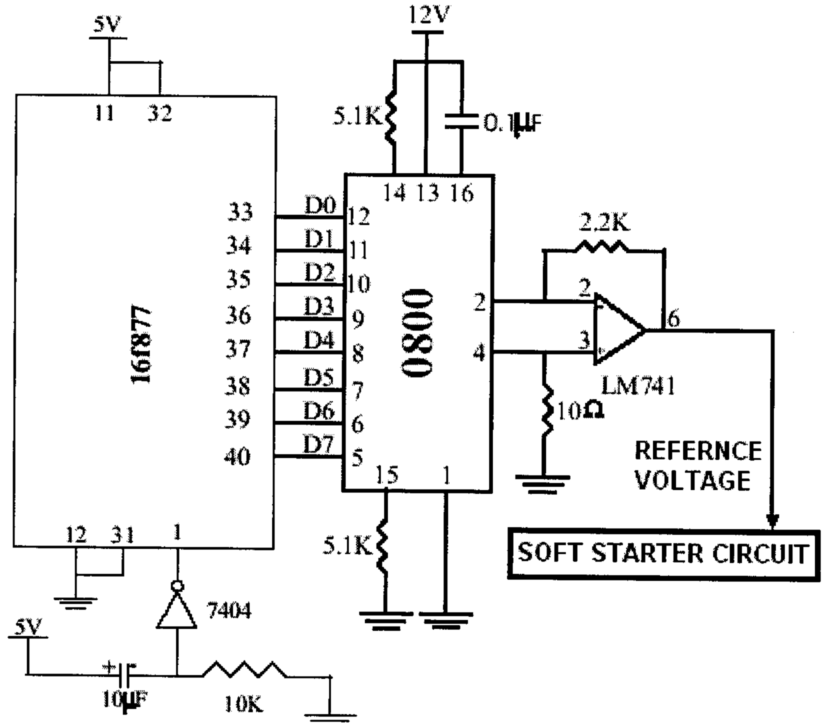
These soft starters, confirm to latest standard specifications and these are compact in size as well as most economic in comparison to fully automatic Auto Transformer Starters. Here the energy is saved by means of controlling starting current which in turns reduces the maximum demand. Soft starters limit power line disturbances and reduce inrush currents, while reducing stress on the motor to extend operational life and minimize downtime. Start times are selectable from 2 to 15s. The device is suitable for either 50 or 60Hz operation.

The current limiting starting method eliminates the current transition point found in star-delta applications, reducing the mechanical and electrical shock on the system. This kit is ideal for applications such as compressors, chillers, pumps, conveyors and crushers where direct-online starting could result in damage to mechanical systems. Since the size and cost of this project is very much less compared to other techniques, there is a future scope for this project in industries of very large power rating motors.

APPENDIX I

FUNCTION OF DAC 0800

FIG 6.1 SOFT STARTER WITH DAC 0800



The above figure shows the connection between PIC, DAC (0800) and soft starter circuit. The reference voltage for soft starting operation is set through PIC. The output from PIC will be in digital format & it has to be converted into analog form. The conversion process is done by DAC 0800.

The purpose of DAC is to convert a binary word to a proportional current or voltage. The characteristics of DAC are

i) RESOLUTION :

The smallest analog increment corresponding to a 1 LSB converter change. It is determined by the number of bits in the input binary word. A converter with 8 binary inputs has 256 output levels, so its resolution is 1 part in 256. The resolution of an 8 bit converter is 0.39 percent.

ii) MONOTONICITY :

A monotonic function has a slope whose sign does not change. A monotonic DAC has an output that changes in the same direction for each increase in the input code. The converse is true for decreasing codes.

iii) OFFSET ERROR :

The output voltage that exists when the input digital code is set to give an ideal output of zero volts. All the digital codes in the transfer curve are offset by the same value. Offset error is usually expressed in LSB's.

iv) SETTLING TIME :

The time from a change in input code until a DAC's output signal remains within +/- ½ LSB of the final value.

v) LINEARITY :

It is a measure of how much the output ramp deviates from a straight line.

The DAC applications with computer:

i) In Compact audio disk player 13 or 14 bit DAC converter is used to convert the binary data read off the disk by a laser to an analog audio signal.

ii) The speech synthesizer IC's contain a DAC to convert stored binary data for words into analog audio signals.

DAC CHIP 0800 :

The DAC 0800 series are monolithic 8 bit high speed current output digital to analog converter (DAC) featuring typical setting time of 100ns. When used as a multiplying DAC, monotonic performance over a 40 to 1 reference current range is possible.

The DAC 0800 series also features high compliance complementary current outputs to allow differential output voltages of 20V peak to peak with simple resistor loads.

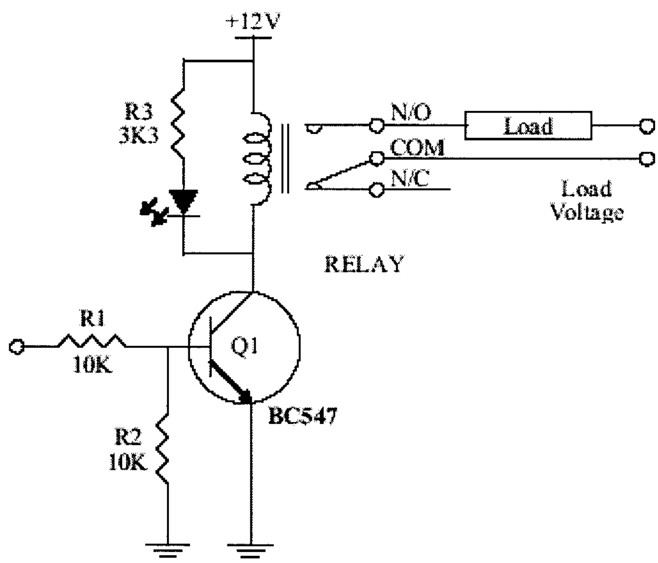
The reference to full scale current matching of better ±1LSB eliminates the need for full scale trims in most applications while the nonlinearities of better than ±0.1% over temperature minimizes system error accumulations. The noise immune inputs of the DAC0800 series will accept TTL levels with the logic threshold pin, V_{lc} grounded. Simple adjustments of the V_{lc} potential will allow direct interface to all logic families. The performance and characteristics of the device are essentially unchanged over the full ±4.5V to ±18V power supply range; power dissipation is only 33mW with ±5V supplies and is independent of the logic input states.

FEATURES :

- Complementary current outputs
- Interface directly with TL, CMOS, PMOS, and others
- 2 quadrant wide range multiplying capability
- Fast setting output current 100ns
- Full scale error ±1 LSB
- Nonlinearity over temperature ±0.1%
- Full scale current drift ±10ppm/°C
- High output compliance ±10V to +18V
- Wide power supply range ±4.5V to ±18V
- Low power consumption 33mW to ±5V
- Low cost

OPERATION OF RELAY CIRCUIT

F1G 6.2 RELAY CIRCUIT



CIRCUIT DIAGRAM DESCRIPTION :

In this circuit transistor BC547 is used as a switch. The control signal is given to the base terminal of the transistor. The collector is attached to the relay coil. Relays are electromechanical devices. The two states of relay are

1. Normally closed
2. Normally opened

We are using normally opened type relay. When the controller output from the PIC is high the transistor will be in the ON state, so relay gets energized and the contactor will close. When the controller output from the PIC is low the transistor will be in the OFF state, so relay is de-energized and the contactor will open. So according to the controller output the contactor will open or close and thus level is maintained.

APPENDIX II

LM741 Operational Amplifier

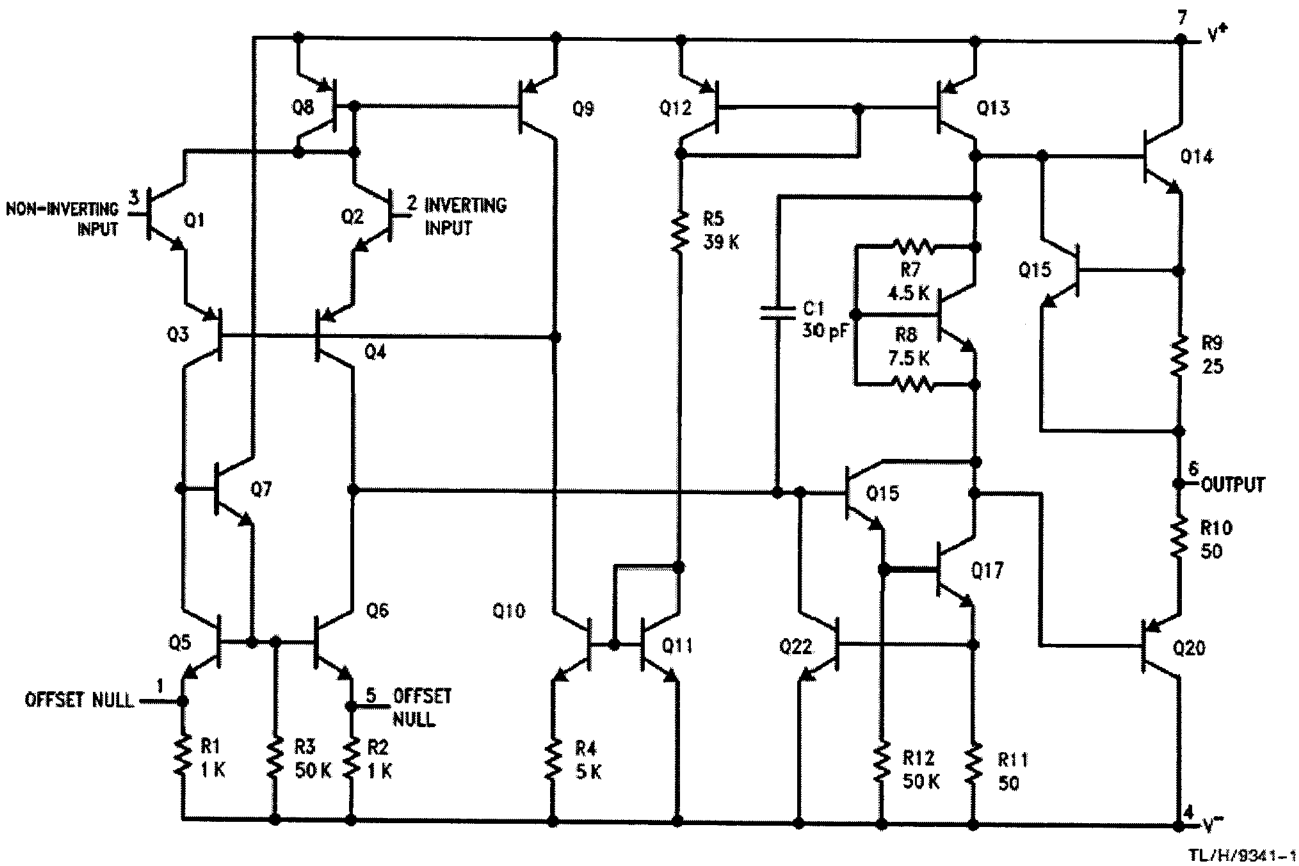
General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

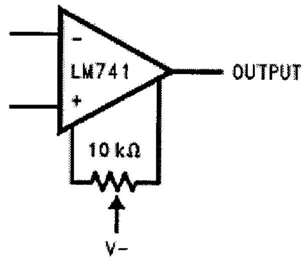
The LM741C/LM741E are identical to the LM741/LM741A except that the LM741C/LM741E have their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Schematic Diagram



TL/H/9341-1

Offset Nulling Circuit



Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.
(Note 5)

	LM741A	LM741E	LM741	LM741C
Supply Voltage	±22V	±22V	±22V	±18V
Power Dissipation (Note 1)	500 mW	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V	±30V
Input Voltage (Note 2)	±15V	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	0°C to +70°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	100°C	150°C	100°C
Soldering Information				
N-Package (10 seconds)	260°C	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C	300°C
M-Package				
Vapor Phase (60 seconds)	215°C	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD Tolerance (Note 6)	400V	400V	400V	400V

Electrical Characteristics (Note 3)

Parameter	Conditions	LM741A/LM741E			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C, V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C, V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V
Large Signal Voltage Gain	$T_A = 25°C, R_L \geq 2\ k\Omega$										
	$V_S = \pm 20V, V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V, V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $R_L \geq 2\ k\Omega$,										
	$V_S = \pm 20V, V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V, V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V, V_O = \pm 2V$	10									V/mV

Electrical Characteristics (Note 3) (Continued)

Parameter	Conditions	LM741A/LM741E			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Output Voltage Swing	$V_S = \pm 20V$ $R_L \geq 10\ k\Omega$ $R_L \geq 2\ k\Omega$	 ±16 ±15									 V V
	$V_S = \pm 15V$ $R_L \geq 10\ k\Omega$ $R_L \geq 2\ k\Omega$				 ±12 ±10	 ±14 ±13		 ±12 ±10	 ±14 ±13		 V V
Output Short Circuit Current	$T_A = 25°C$ $T_{AMIN} \leq T_A \leq T_{AMAX}$	10 10	25	35 40		25			25		mA mA
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$ $R_S \leq 10\ k\Omega, V_{CM} = \pm 12V$ $R_S \leq 50\Omega, V_{CM} = \pm 12V$	 80	 95		 70	 90		 70	 90		 dB dB
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$ to $V_S = \pm 5V$ $R_S \leq 50\Omega$ $R_S \leq 10\ k\Omega$	 86	 96		 77	 96		 77	 96		 dB dB
Transient Response Rise Time Overshoot	$T_A = 25°C$, Unity Gain		 0.25 6.0	 0.8 20		 0.3 5			 0.3 5		 μs %
Bandwidth (Note 4)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/μs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$ $V_S = \pm 20V$ $V_S = \pm 15V$		 80	 150		 50	 85		 50	 85	 mW mW
LM741A	$V_S = \pm 20V$ $T_A = T_{AMIN}$ $T_A = T_{AMAX}$			 165 135							 mW mW
LM741E	$V_S = \pm 20V$ $T_A = T_{AMIN}$ $T_A = T_{AMAX}$			 150 150							 mW mW
LM741	$V_S = \pm 15V$ $T_A = T_{AMIN}$ $T_A = T_{AMAX}$					 60 45	 100 75				 mW mW

Note 1: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100°C/W	100°C/W	170°C/W	195°C/W
θ_{jC} (Junction to Case)	N/A	N/A	25°C/W	N/A

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Unless otherwise specified, these specifications apply for $V_S = \pm 15V$, $-55°C \leq T_A \leq +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \leq T_A \leq +70°C$.

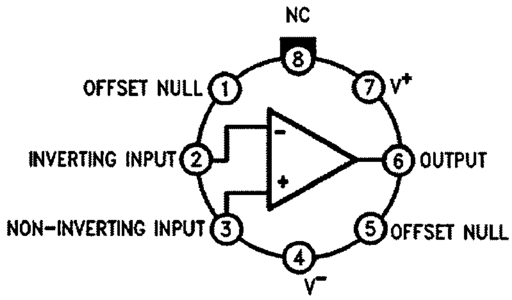
Note 4: Calculated value from: BW (MHz) = 0.35/Rise Time(μs).

Note 5: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 6: Human body model, 1.5 kΩ in series with 100 pF.

Connection Diagrams

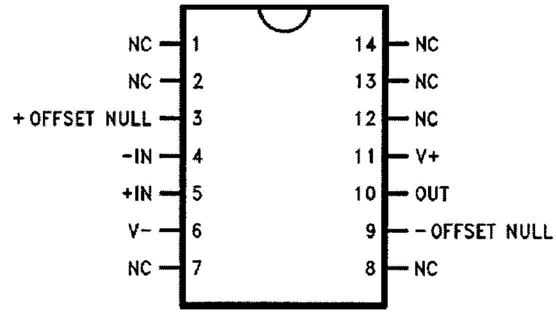
Metal Can Package



TL/H/9341-2

Order Number LM741H, LM741H/883*, LM741AH/883 or LM741CH
See NS Package Number H08C

Ceramic Dual-In-Line Package



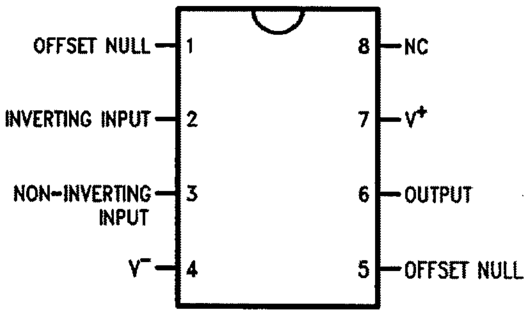
TL/H/9341-5

Order Number LM741J-14/883*, LM741AJ-14/883**
See NS Package Number J14A

*also available per JM38510/10101

**also available per JM38510/10102

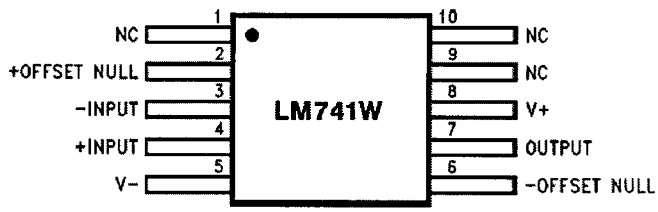
Dual-In-Line or S.O. Package



TL/H/9341-3

Order Number LM741J, LM741J/883, LM741CM, LM741CN or LM741EN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak



TL/H/9341-6

Order Number LM741W/883
See NS Package Number W10A

National Semiconductor

LM555
Timer

General Description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.

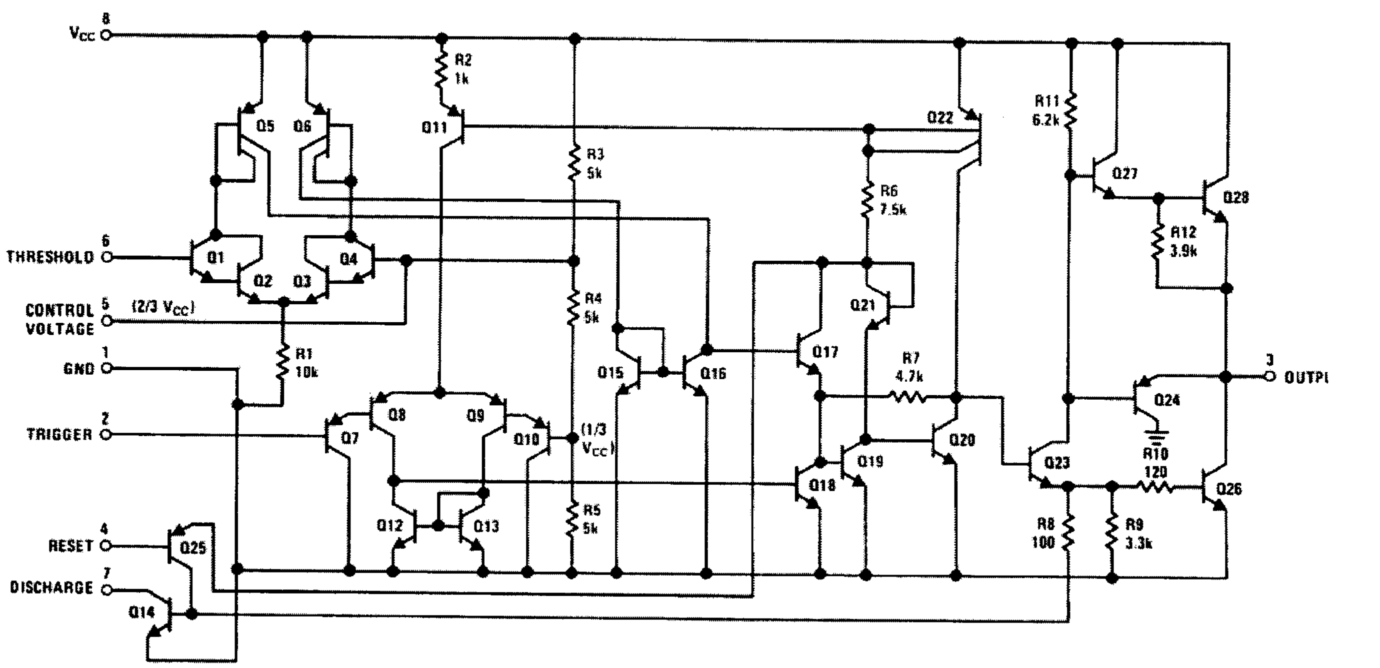
Features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output
- Available in 8-pin MSOP package

Applications

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

Schematic Diagram



Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+18V
Power Dissipation (Note 3)	
LM555CM, LM555CN	1180 mW
LM555CMM	613 mW
Operating Temperature Ranges	
LM555C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Soldering Information	
Dual-In-Line Package	
Soldering (10 Seconds)	260°C
Small Outline Packages	
(SOIC and MSOP)	
Vapor Phase (60 Seconds)	215°C
Infrared (15 Seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 1, 2)

(T_A = 25°C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits LM555C Min	Typ	Max	Units
Supply Voltage		4.5		16	V
Supply Current	V_{CC} = 5V, R_L = ∞ V_{CC} = 15V, R_L = ∞ (Low State) (Note 4)		3 10	6 15	mA
Timing Error, Monostable					
Initial Accuracy			1		%
Drift with Temperature	R_A = 1k to 100kΩ, C = 0.1µF, (Note 5)		50		ppm/°C
Accuracy over Temperature			1.5		%
Drift with Supply			0.1		%/V
Timing Error, Astable					
Initial Accuracy			2.25		%
Drift with Temperature	R_A, R_B = 1k to 100kΩ, C = 0.1µF, (Note 5)		150		ppm/°C
Accuracy over Temperature			3.0		%
Drift with Supply			0.30		%/V
Threshold Voltage			0.667		x V_{CC}
Trigger Voltage	V_{CC} = 15V		5		V
	V_{CC} = 5V		1.67		V
Trigger Current			0.5	0.9	µA
Reset Voltage		0.4	0.5	1	V
Reset Current			0.1	0.4	mA
Threshold Current	(Note 6)		0.1	0.25	µA
Control Voltage Level	V_{CC} = 15V V_{CC} = 5V	9 2.6	10 3.33	11 4	V
Pin 7 Leakage Output High			1	100	nA
Pin 7 Sat (Note 7)					
Output Low	V_{CC} = 15V, I_7 = 15mA		180		mV
Output Low	V_{CC} = 4.5V, I_7 = 4.5mA		80	200	mV

Electrical Characteristics (Notes 1, 2) (Continued)

(T_A = 25°C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits			Units
		LM555C			
		Min	Typ	Max	
Output Voltage Drop (Low)	V_{CC} = 15V				
	I_{SINK} = 10mA		0.1	0.25	V
	I_{SINK} = 50mA		0.4	0.75	V
	I_{SINK} = 100mA		2	2.5	V
	I_{SINK} = 200mA		2.5		V
	V_{CC} = 5V				
	I_{SINK} = 8mA				V
	I_{SINK} = 5mA		0.25	0.35	V
Output Voltage Drop (High)	I_{SOURCE} = 200mA, V_{CC} = 15V		12.5		V
	I_{SOURCE} = 100mA, V_{CC} = 15V	12.75	13.3		V
	V_{CC} = 5V	2.75	3.3		V
Rise Time of Output			100		ns
Fall Time of Output			100		ns

Note 1: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is fu tional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which gu antee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limi given, however, the typical value is a good indication of device performance.

Note 3: For operating at elevated temperatures the device must be derated above 25°C based on a +150°C maximum junction temperature and a thermal resistar of 106°C/W (DIP), 170°C/W (S0-8), and 204°C/W (MSOP) junction to ambient.

Note 4: Supply current when output high typically 1 mA less at V_{CC} = 5V.

Note 5: Tested at V_{CC} = 5V and V_{CC} = 15V.

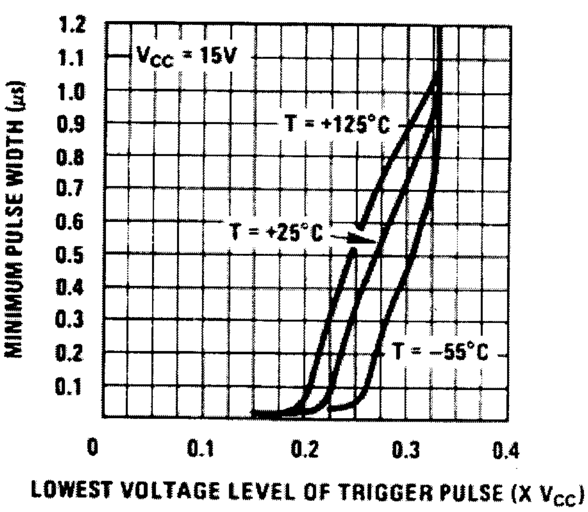
Note 6: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total ($R_A + R_B$) is 20MΩ.

Note 7: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

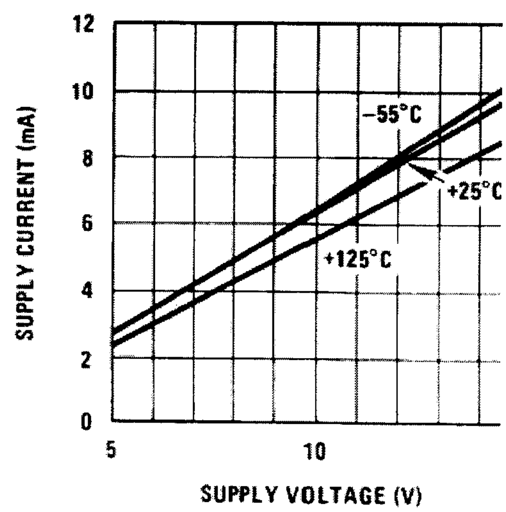
Note 8: Refer to RETS555X drawing of military LM555H and LM555J versions for specifications.

Typical Performance Characteristics

Minimuim Pulse Width Required for Triggering



Supply Current vs. Supply Voltage



Applications Information

MONOSTABLE OPERATION

In this mode of operation, the timer functions as a one-shot (*Figure 1*). The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.

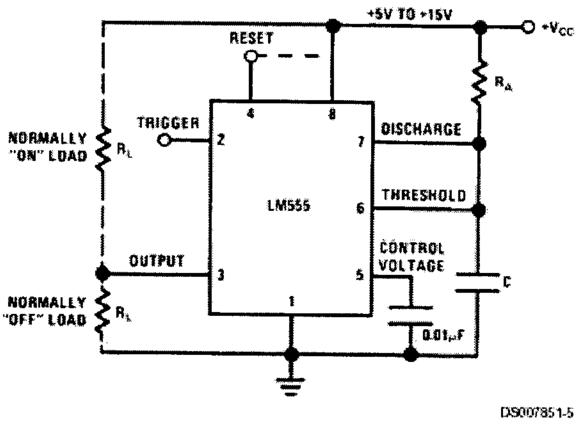
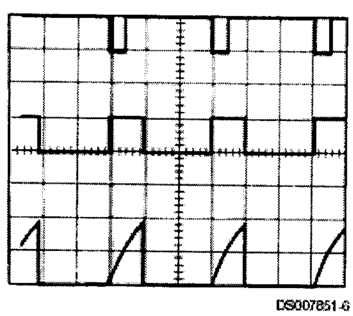


FIGURE 1. Monostable

The voltage across the capacitor then increases exponentially for a period of $t = 1.1\ R_A C$, at the end of which time the voltage equals 2/3 V_{CC}. The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state. *Figure 2* shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing internal is independent of supply.



V_{CC} = 5V — Top Trace: Input 5V/Div.
TIME = 0.1 ms/DIV. — Middle Trace: Output 5V/Div.
R_A = 9.1kΩ — Bottom Trace: Capacitor Voltage 2V/Div.
C = 0.01µF

FIGURE 2. Monostable Waveforms

During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit so long as the trigger input is returned high at least 10µs before the end of the timing interval. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

NOTE: In monostable operation, the trigger should be driven high before the end of timing cycle.

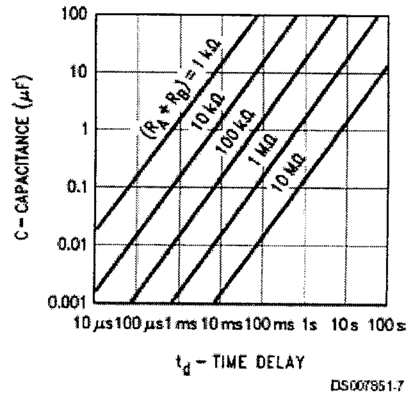


FIGURE 3. Time Delay

ASTABLE OPERATION

If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.

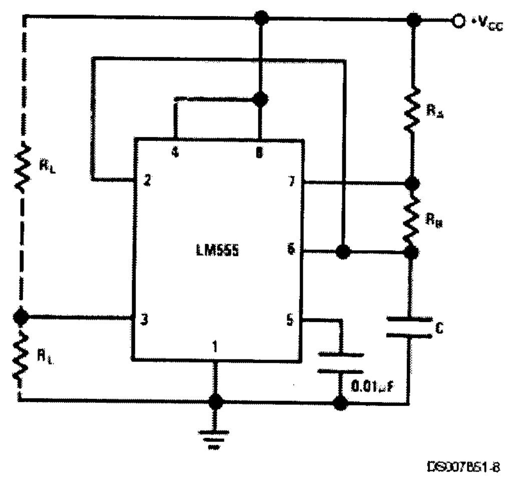
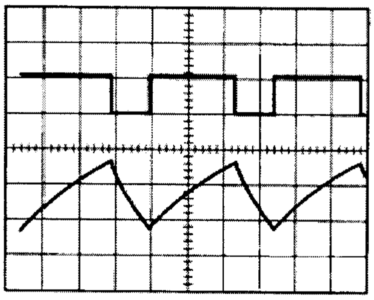


FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Figure 5 shows the waveforms generated in this mode of operation.



DS007851-9

V_{CC} = 5V Top Trace: Output 5V/Div.
TIME = 20μs/DIV. Bottom Trace: Capacitor Voltage 1V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01μF

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

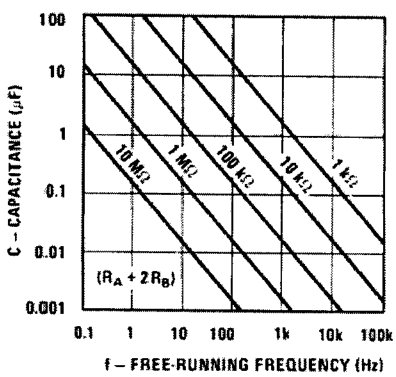
The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B}$$

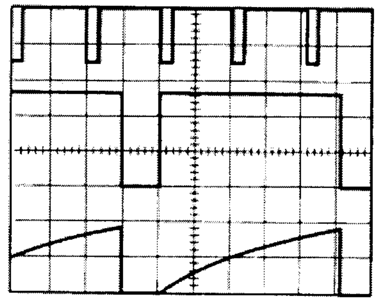


DS007851-10

FIGURE 6. Free Running Frequency

FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.



DS007851-11

V_{CC} = 5V Top Trace: Input 4V/Div.
TIME = 20μs/DIV. Middle Trace: Output 2V/Div.
R_A = 9.1kΩ Bottom Trace: Capacitor 2V/Div.
C = 0.01μF

FIGURE 7. Frequency Divider

PULSE WIDTH MODULATOR

When the timer is connected in the monostable mode ai triggered with a continuous pulse train, the output pul: width can be modulated by a signal applied to pin 5. *Figu 8* shows the circuit, and in *Figure 9* are some wavefoı examples.

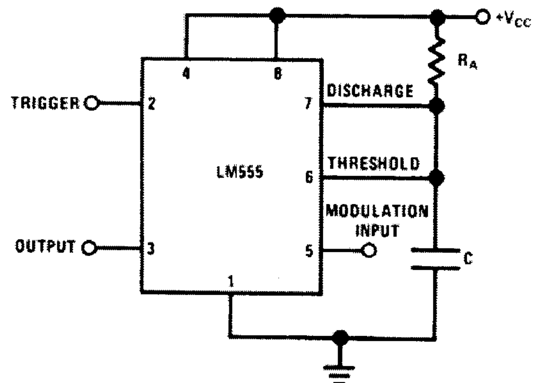


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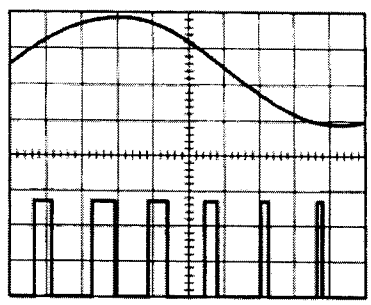
FIGURE 8. Pulse Width Modulator



DS007851-13

V_{CC} = 5V Top Trace: Modulation 1V/Div.
TIME = 0.2 ms/DIV. Bottom Trace: Output Voltage 2V/Div.
R_A = 9.1kΩ
C = 0.01μF

FIGURE 9. Pulse Width Modulator

PULSE POSITION MODULATOR

This application uses the timer connected for astable operation, as in *Figure 10*, with a modulating signal again applied to the control voltage terminal. The pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied. *Figure 11* shows the waveforms generated for a triangle wave modulation signal.

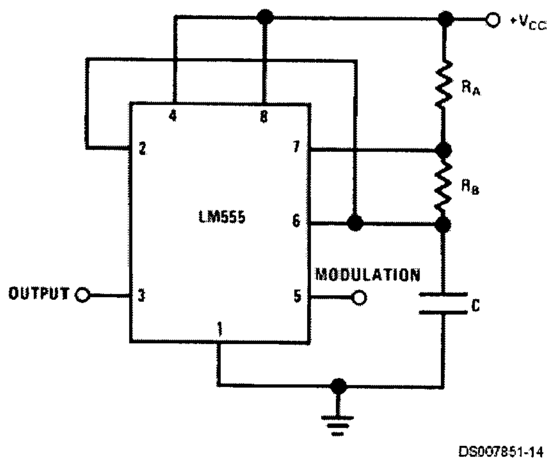
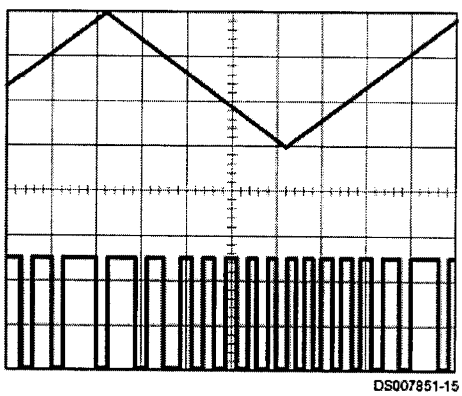


FIGURE 10. Pulse Position Modulator



V_{CC} = 5V
TIME = 0.1 ms/DIV.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01μF

Top Trace: Modulation Input 1V/Div.
Bottom Trace: Output 2V/Div.

FIGURE 11. Pulse Position Modulator

LINEAR RAMP

When the pullup resistor, R_A, in the monostable circuit is replaced by a constant current source, a linear ramp is generated. *Figure 12* shows a circuit configuration that will perform this function.

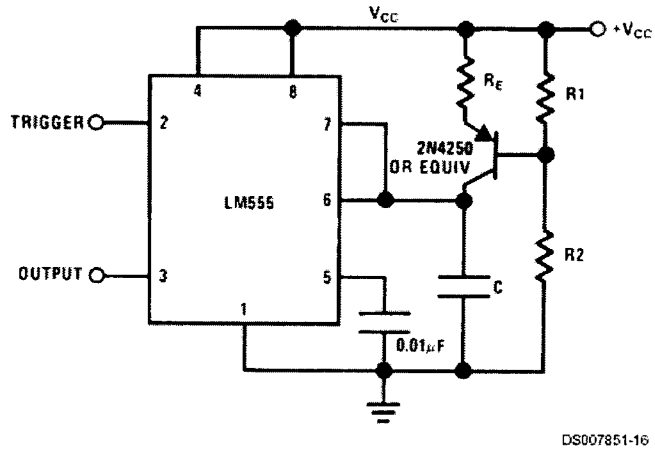


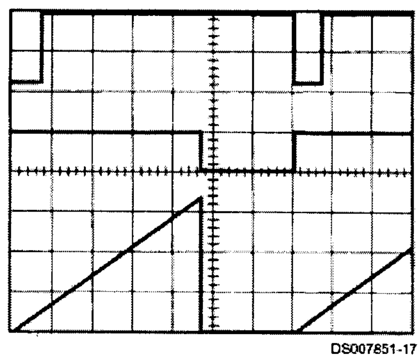
FIGURE 12.

Figure 13 shows waveforms generated by the linear ramp. The time interval is given by:

$$T = \frac{2/3\, V_{CC} R_E (R_1 + R_2) C}{R_1 V_{CC} - V_{BE} (R_1 + R_2)}$$

$$V_{BE} \cong 0.6V$$

$$V_{BE} \cong 0.6V$$



V_{CC} = 5V
TIME = 20μs/DIV.
R_1 = 47kΩ
R_2 = 100kΩ
R_E = 2.7 kΩ
C = 0.01 μF

Top Trace: Input 3V/Div.
Middle Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 1V/Div.

FIGURE 13. Linear Ramp

Applications Information (Continued)

50% DUTY CYCLE OSCILLATOR

For a 50% duty cycle, the resistors R_A and R_B may be connected as in *Figure 14.* The time period for the output high is the same as previous, $t_1 = 0.693\ R_A\ C$. For the output low it is $t_2 =$

$$\left[(R_A R_B)/(R_A + R_B)\right] C\ \ell n \left[\frac{R_B - 2R_A}{2R_B - R_A}\right]$$

Thus the frequency of oscillation is

$$f = \frac{1}{t_1 + t_2}$$

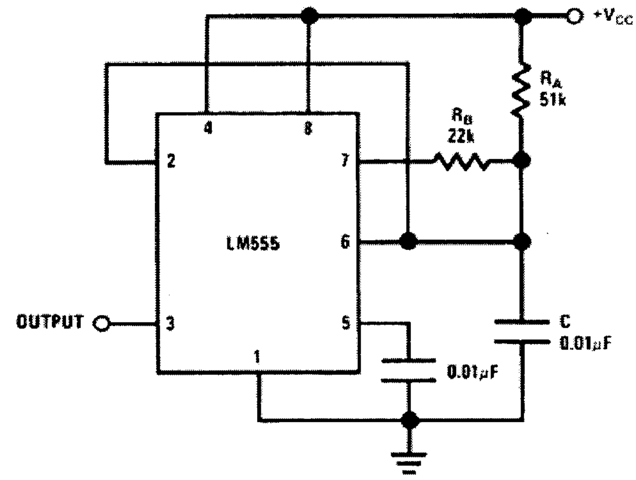
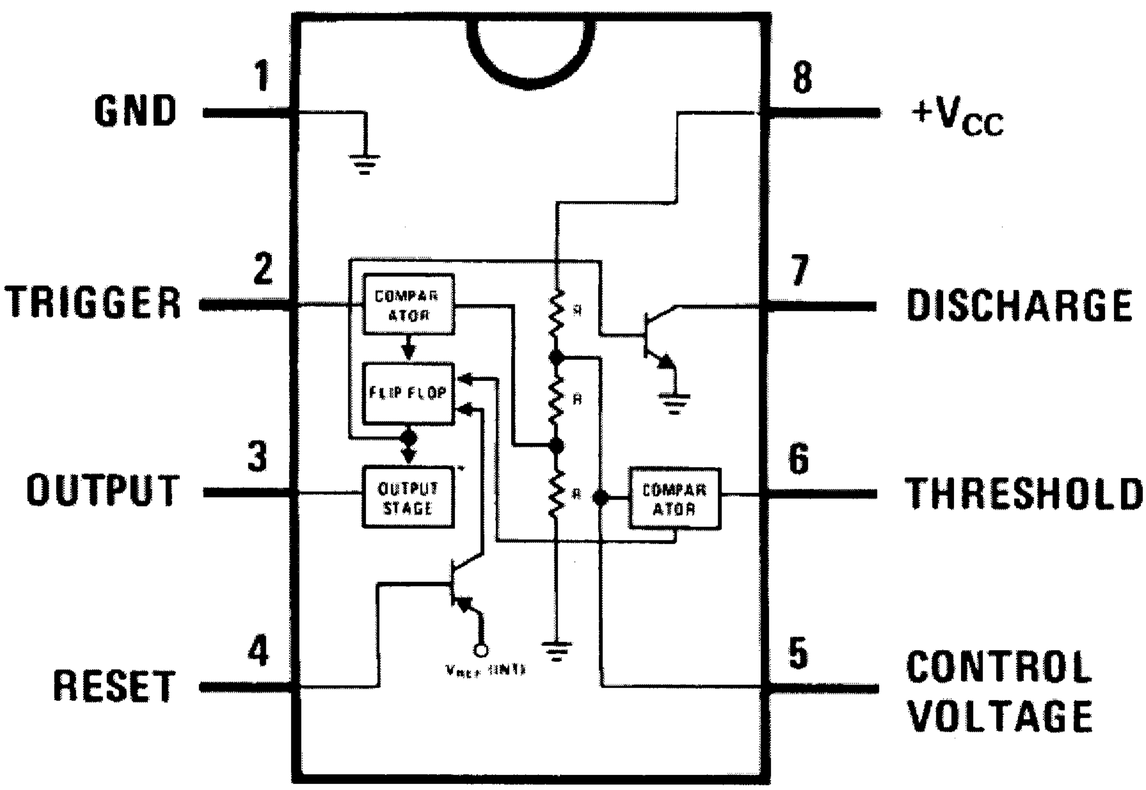


FIGURE 14. 50% Duty Cycle Oscillator

Note that this circuit will not oscillate if R_B is greater than 1/ R_A because the junction of R_A and R_B cannot bring pin down to 1/3 V_{CC} and trigger the lower comparator.

CONNECTION DIAGRAM

Dual-In-Line, Small Outline and Molded Mini Small Outline Packages



TOP VIEW

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